Chemical Engineering Progress

APRIL 1956

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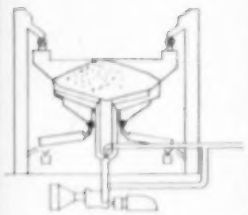

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- WHAT THE EQUIPMENT BUILDERS CAN ECONOMICALLY PRODUCE

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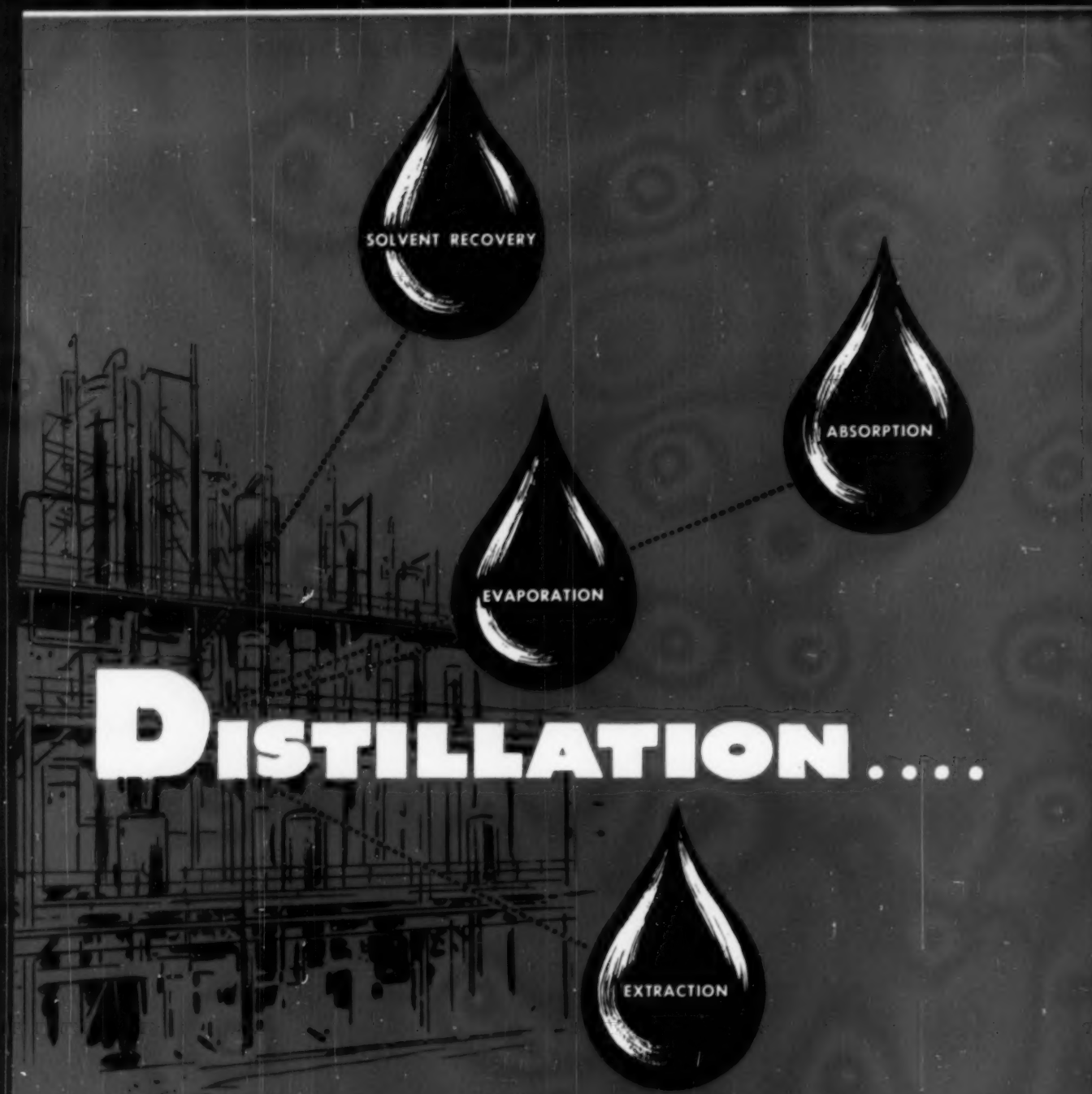

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Chemical Engineering Progress

what's in this issue

April, 1956 • Volume 52, No. 4

How Well Does the Industry Progress / 49

Trends—Often, much can be and is deduced from the annual reports of the major chemical producing companies. Our analysis of the present crop of reports indicates reasons why there seems such a decided possibility 1956 may surpass 1955 in manufacturing output.

C.E.P. SPECIAL FEATURE

Standardization of Processing Equipment

The beginning of a new era / 129

J. C. Lawrence—Much of the key equipment closest to the heart of a chemical engineering process has never been seriously regarded as standardizable. This was partly due to the degree of advantage realized through custom specifications. Now it appears that a cooperative effort between buyers and sellers of chemical centrifugal pumps will bring desired results.

What the chemical industry wants / 130

D. C. Brand—50% of the initial investment for centrifugal pumps in the chemical industry is spent each year on replacement and maintenance. A total as high as $6.8 million could be saved within the industry each year upon achievement of a standard dimensional framework.

What the centrifugal pump manufacturers can do / 135

M. L. Murdock—Dimensional interchangeability of pumps will result ultimately in a completely new line of pumps offered by the manufacturers. This could cost each pump company approximately $200,000.

Size reduction as a nucleation process / 139

W.H.C. Simmonds—In spite of there being no readily evident common relation between such diverse operations as crushing, boiling and dropwise condensation, and crystallization, all do represent the creation of new interfaces.

Chemical engineering aspects of jet propulsion / 143

Louis R. Rapp—There is a surprisingly large number of problems in the field of jet propulsion which require the services of the chemical engineer.

Pebble furnace process fixes atmospheric nitrogen / 149

E. D. Ermenc—The new Wisconsin thermal process has

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departmental features

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Classified / 101 • News and notes of A.I.Ch.E. / 110 • NEW: About our authors / 44

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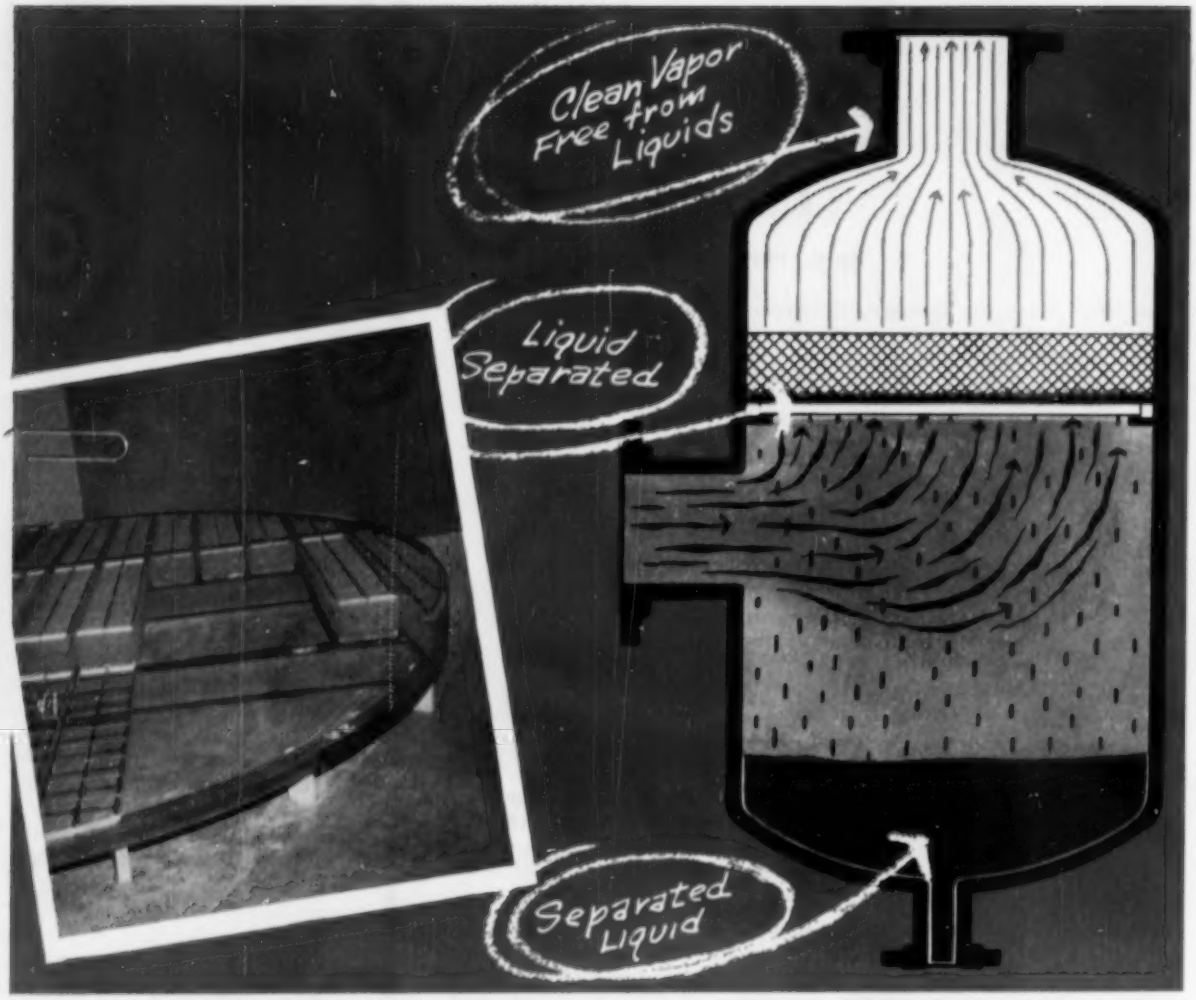

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what's in this issue

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been given a thorough trying out at a 40 ton/day (HNO_3) demonstration plant at Sunflower Ordnance Works.

The chemical engineers' nuclear future / 154

C. Rogers McCullough—There's a lot more to our nuclear future than atomic power. Among the promising and exciting uses of the atomic pile of the future may be as furnaces for chemical reactions taking place at temperatures as high as 3000 to 4000° F.

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D. C. Lee, G. Z. Moore, & F. D. Mayfield—These natural circulation evaporators are widely used in the chemical industry, although little has been published on their heat transfer coefficients and maximum allowable heat fluxes.

Freeze seal valves and pumps solve liquid metals problem / 157

R. Cygan & A. M. Stelle—The "freezing" of molten metal around stationary or rotating shafts, slip expansion joints in piping, instrument lead-throughs, and other applications offers an easy solution to what might otherwise be a serious problem of containment.

The high efficiency engine as a compressor driver / 165

G. C. Woodard & T. O. Kuivinen—The large diesel and gas engines used to drive compressors in the process industries have undergone important developments in the last few years.

New Orleans reminder / 51

Late illustrated news rushes from the scene of the next Institute meeting should remind you to go—if you haven't already decided.

Survey of project engineering—Part II / 52

C. W. Barkow—In the March C.E.P., general results and conclusions were given. Now the author continues with more specific information about his sampling and results.

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Industrial News—The story on General Aniline's new high pressure acetylene synthesis plant, plus others.

Measuring performance of engineers & scientists / 78

R. A. Kinckiner—The techniques used for assuring each professional employee in a sizable organization a fair evaluation of his services.

Los Angeles meeting pictures and report / 84

What smog? . . . roundtable on project economics . . . panel advises on supervising professional employees . . . other subjects.

Murphree made missiles czar / 92

Prominent chemical engineer, who was until recently a director of the Institute, now runs our nation's program for development of the intercontinental (and other) missiles.

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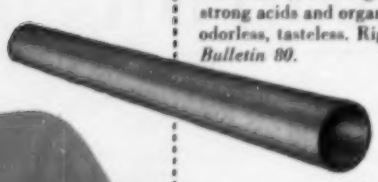

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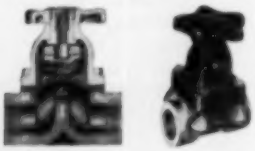

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LETTERS TO THE EDITOR

A Note of Caution

I was interested to see that you considered that a table in a paper I wrote for the United Nations Atomic Energy Conference held at Geneva last year was of sufficient interest to warrant reproduction in your journal. ["Criteria for selection of equipment for separation processes." C.E.P., February, 1956, page 78.]

However, I would like to point out that you have committed the ethical sin of only partial quotation. The table as reproduced in your journal appears over-authoritative. In the original paper the following cautionary sentences were included:

> "The figures given for the total activity present in a cell are only relative and would be affected by the size of plant and of containing cell. Also, the remarks on the possibility of entering the cell are only a rough guide and are subject to variation for different types of plant."

A note was also included at the foot of the table.

The effect of the presence of radioactivity on the design and servicing of plant for nuclear reactors as well as for separation processes is of considerable interest at the present time. I was rather alarmed at the oversimplification of these complex problems in your quotation.

Without attempting a detailed, quantitative analysis it is apparent that the following factors would affect the radiation background in a cell containing plant handling radioactive materials:

1. The activity and energy of the source.
2. The size of the source and its nature, e.g., whether in solution in a solvent which would provide "self-absorption" of radiation.
3. The size of the cell.

(*Continued on page* 12)

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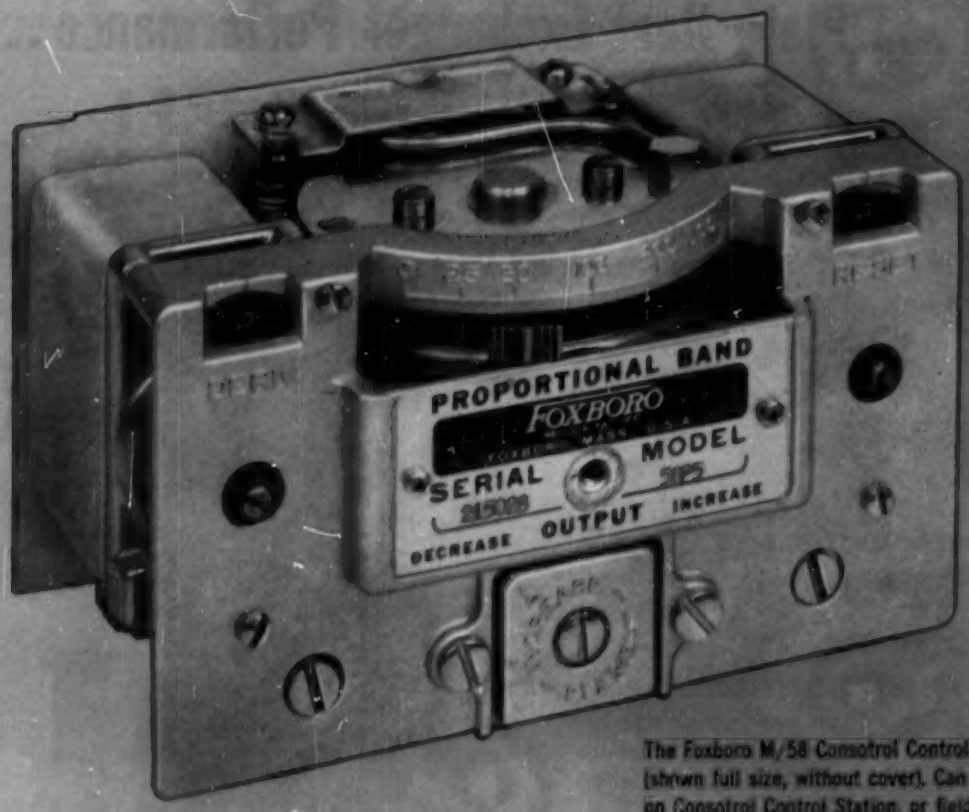

The Foxboro M/58 Consotrol Controller (shown full size, without cover). Can be panel-mounted on Consotrol Control Station, or field-mounted.

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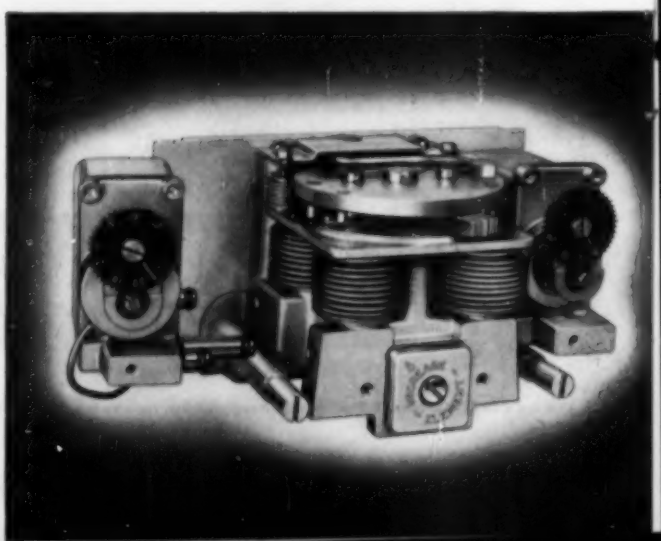

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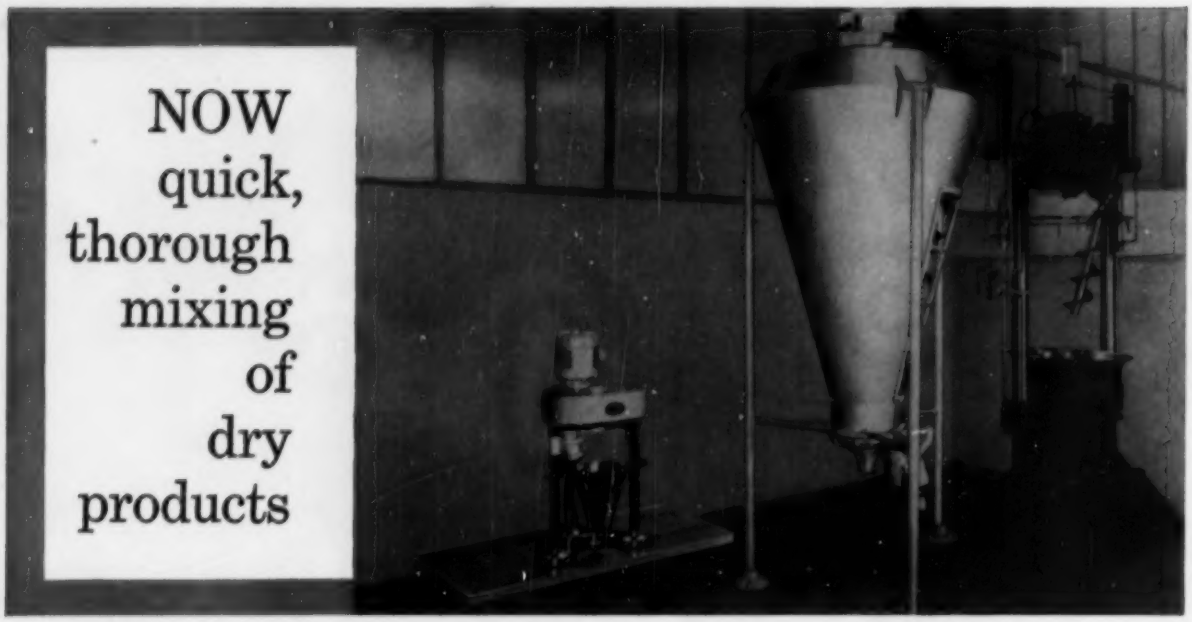

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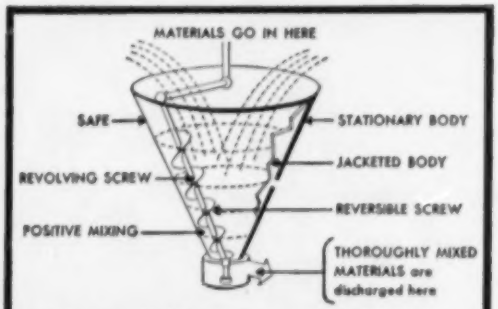

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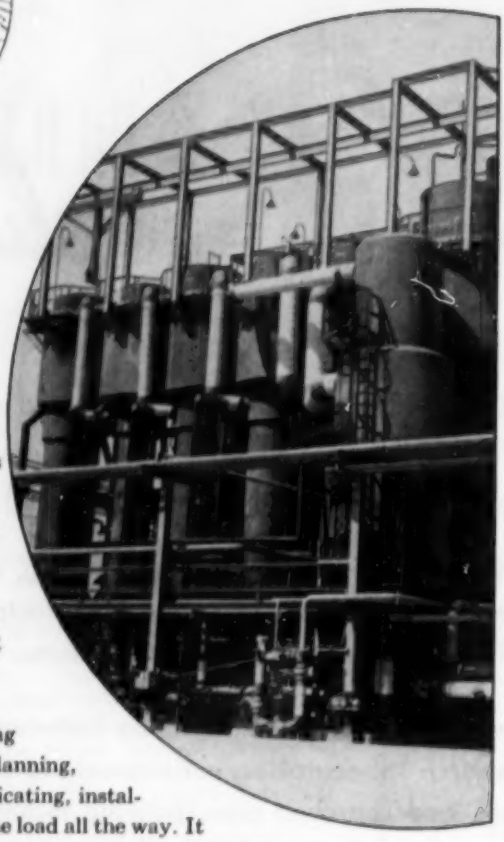

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Goslin-Birmingham's complete, integrated organization is always at your disposal. Our process engineers are available for prompt, on-the-spot technical consultation and planning. G-B takes YOUR processing problem and comes up with the solution...from planning board to installation. Planning, designing, casting, fabricating, installing...G-B shoulders the load all the way. It will pay to solve your processing problems the G-B way.

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Letters to the Editor

(Continued from page 6)

4. The orientation of plant in the cell.
5. The nature of the shielding and other materials in the cell. They can influence the reflection and scattering of radiation.

With plants handling more than moderate amounts of radioactivity, it is usually necessary to remove process materials from the plant, e.g., by draining, and to decontaminate the plant by washing it out with "inactive" process liquors and special decontaminating agents. A plant designed with a view to facilitating operations will clearly be in a more favorable position for so-called "contact" servicing than one in which these aspects are ignored. Ease of draining is a clear design requirement. The material of which the plant is made can be important since some materials are easier to decontaminate than others. The nature of the process materials can affect the extent to which materials of construction become radioactive, e.g., radioactive isotopes can exchange with their inactive counterparts in alloy steels.

For the above reasons it is usually very difficult, if not impossible, to predetermine the radiation background that will exist in a cell and, hence the length of time operators may be permitted to remain in the area. Some estimate must be made since the servicing philosophy selected vitally affects the design of the plant and its containing cell. In the design of the first radioactive plants conservative approaches were necessarily taken to these problems with the result that those plants were overexpensive. Considerable experience has now been accumulated on these matters, experience that is locked up in the files and reports of the operating factories. In the interests of furthering the technology in these new fields, you may be interested in inviting contributions from persons with the necessary experience. The published papers by Harty (*1*), and by Lemon and Reid (*2*) may be of interest to you as showing that this is not all "classified" information.

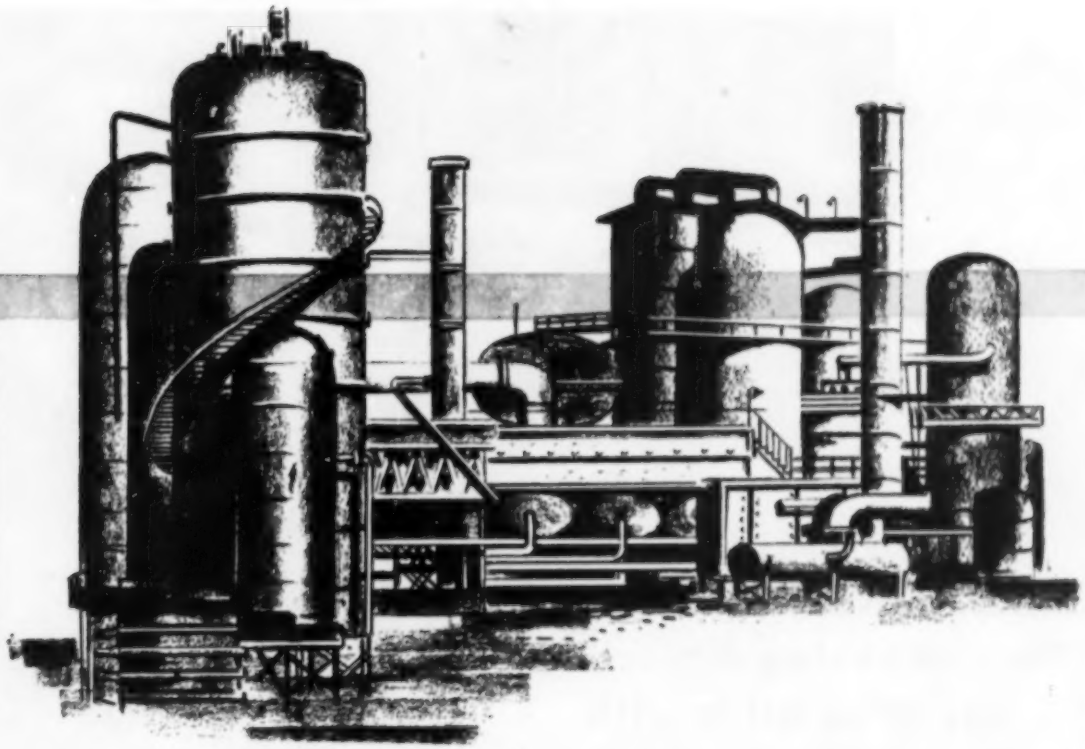
Literature Cited

1. Harty, W. M., *Chem. Eng. Progr. Symposium Series No. 13. Nuclear Engineering—Part III*, **50**, p. 115 (1954).
2. Lemon and Reid. International Conference on the Peaceful Uses of Atomic Energy, Geneva (1955).

C. M. Nicholls

Harwell, England

(*More Letters to the Editor on page* 18)



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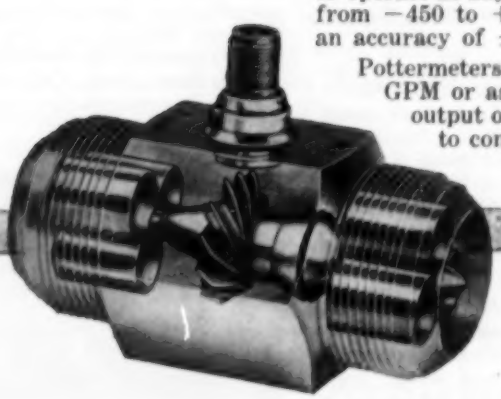
WHETHER you're developing a new process or modernizing an old one—investigate the unique characteristics of the *bearingless Pottermeter.*

This electronic flowmeter—easily installed in any type of piping to operate at any angle, at any pressure and at temperatures from −450 to +1200°F, measures flow of any liquid with an accuracy of ±½ of 1%.

Pottermeters are available to measure flows as low as 0.07 GPM or as high as 3,000 GPM. The inherently linear output of the Pottermeter makes it ideal for systems to control either flow rate or total flow.



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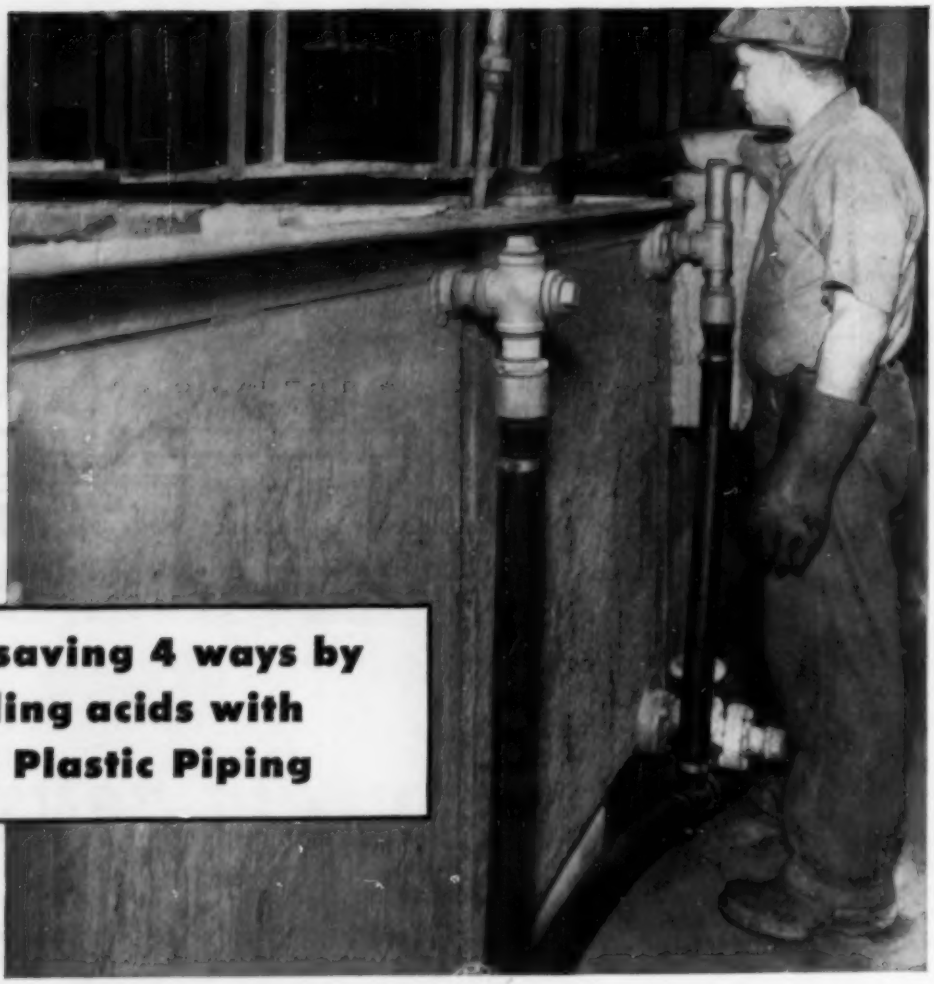


They're saving 4 ways by handling acids with Crane Plastic Piping

THE CASE HISTORY— Globe-Union Inc., leading storage battery builder, in its Milwaukee plant, might have decided plastic piping wasn't for them and let it go at that. Instead, they gave Crane plastic products a fair trial, and here are the results.

On hydrochloric acid lines to zinc-plating tanks, the metal pipe and fittings formerly used had to be replaced completely about every month. Corrosion was the cause.

With Crane polyethylene pipe and Crane plastic fittings in this same service, after more than 3 months there is no sign of deterioration and no apparent need of early replacement.

On battery test tanks, Crane plastic piping, exposed to built-up sulphuric acid concentration, looks good as new after more than 4 months' service.

Savings with Crane plastic piping are adding up 4 ways. Plastic cancels the need for costlier metal pipe. It is installed in a fraction of the time it takes for metal pipe and fittings. It reduces installation to a one-man job with simple hand tools. The longer life of plastic is saving replacement, maintenance and housekeeping costs.

Proved in severest services, Crane plastic piping is giving Globe-Union equal satisfaction on many low-pressure air and water lines. Here freedom from sweating is another advantage of plastic.

Once you know the facts of quality-designed, quality-made Crane polyethylene pipe and Crane plastic insert fittings, you, too, will see many opportunities for saving with this modern piping. Call your local Crane Representative today, or write to address below.

Crane adapter makes plastic-to-metal joints easy

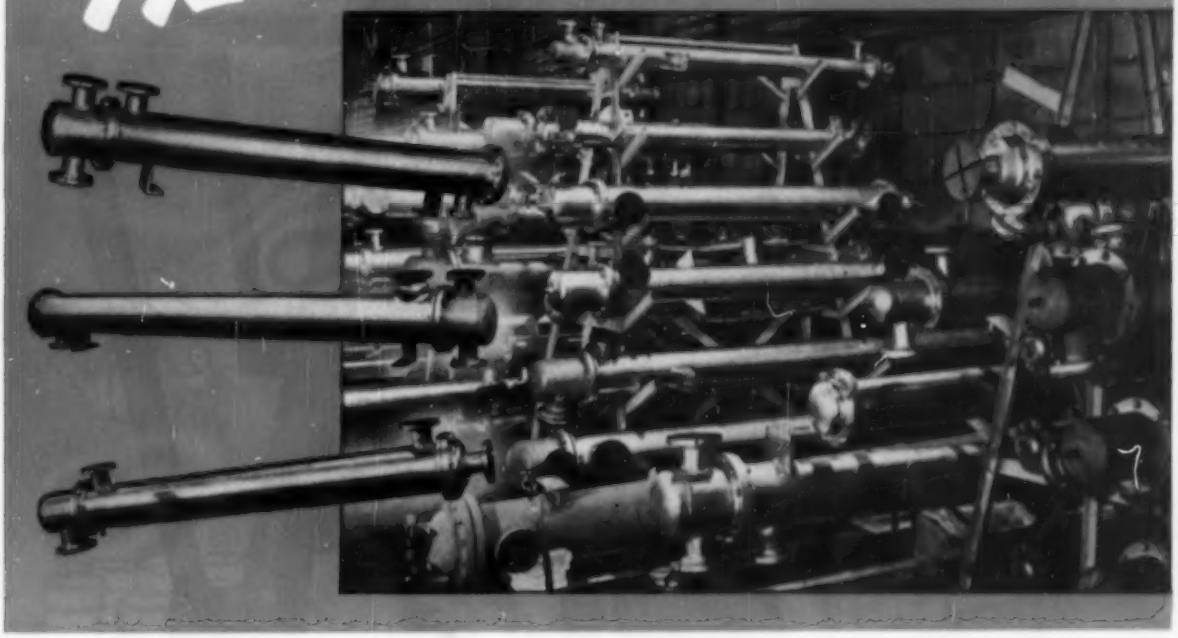
CRANE PLASTIC PIPING

VALVES • FITTINGS • PIPE • KITCHENS • PLUMBING • HEATING

Since 1855—Crane Co., General Offices: Chicago 5, Ill. Branches and Wholesalers Serving All Areas

Struthers Wells

Standard HEAT EXCHANGERS



Struthers Wells now offers a line of Standard heat exchangers—in sizes from 20 to 400 square feet of surface—including fixed tube sheet, floating head and U-tube units. Condensers, coolers, heaters and reboilers can be supplied in single and multipass tube arrangements.

Standard heat exchanger construction includes materials of carbon steel, non-ferrous alloy, and stainless alloys Type 304 and Type 316. Equipment meets highest construction standards, including ASME Code and TEMA Class A.

Typical units are illustrated above, including a partial view of those in stock, ready for immediate shipment. Standardization of design and quantity manufacture enables us to offer this equipment at very reasonable cost.

STRUTHERS WELLS PRODUCTS

PROCESSING EQUIPMENT DIVISION

Crystallizers . . . Direct Fired Heaters . . . Evaporators . . . Heat Exchangers . . . Mixing and Blending Units . . . Quick Opening Doors . . . Special Carbon and Alloy Processing Vessels . . . Synthesis Converters

BOILER DIVISION

BOILERS for Power and Heat . . . High and Low Pressure . . . Water Tube . . . Fire Tube . . . Package Units

FORGE DIVISION

Crankshafts . . . Pressure Vessels . . . Hydraulic Cylinders . . . Shafting . . . Straightening and Back-up Rolls

MACHINERY DIVISION

MACHINERY for Sheet and Structural Metal Forming . . . Tangent Benders . . . Folding Machines . . . Roller Table and Tumble Die Bending Machines . . . Press Brakes . . . Punching and Notching Machines . . . Forming Dies

Any Size Available for Quick Delivery!

STRUTHERS WELLS *Corporation*

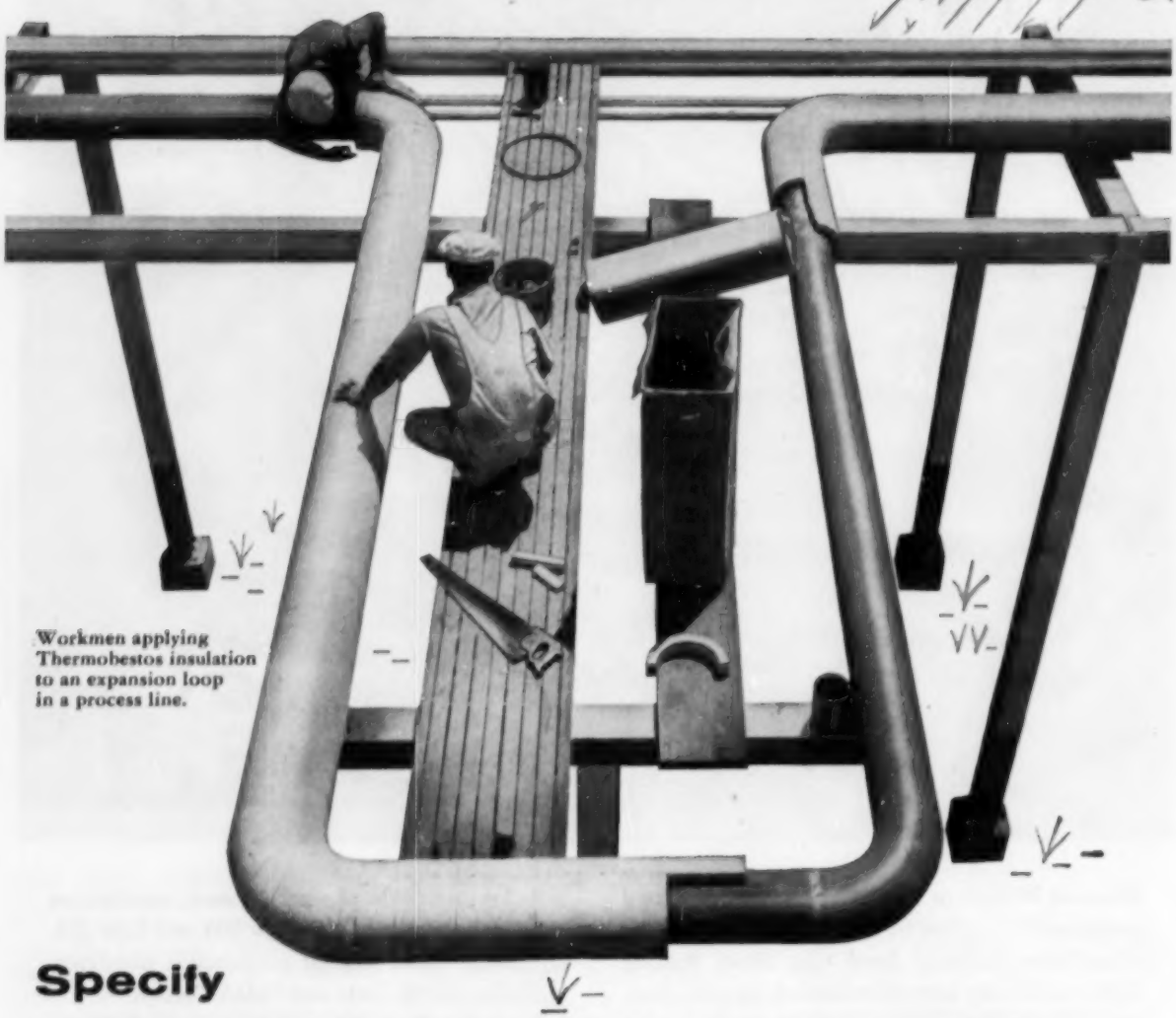
Struthers Wells

WARREN, PA.

Plants at Warren, Pa. and Titusville, Pa.

Offices in Principal Cities

When you're fighting the weather as well as heat loss



Workmen applying Thermobestos insulation to an expansion loop in a process line.

Specify

J-M THERMOBESTOS® the heat insulation designed for outdoor process industries

Here's proof that rugged physical strength and high insulating efficiency can be combined in one material. J-M Thermobestos is strong and rigid, yet light enough for easy handling and fast application. It is not damaged by prolonged wetting. Its hard composition resists crushing and will withstand unusual service abuse. The low conductivity compares favorably with other accepted industrial insulations.

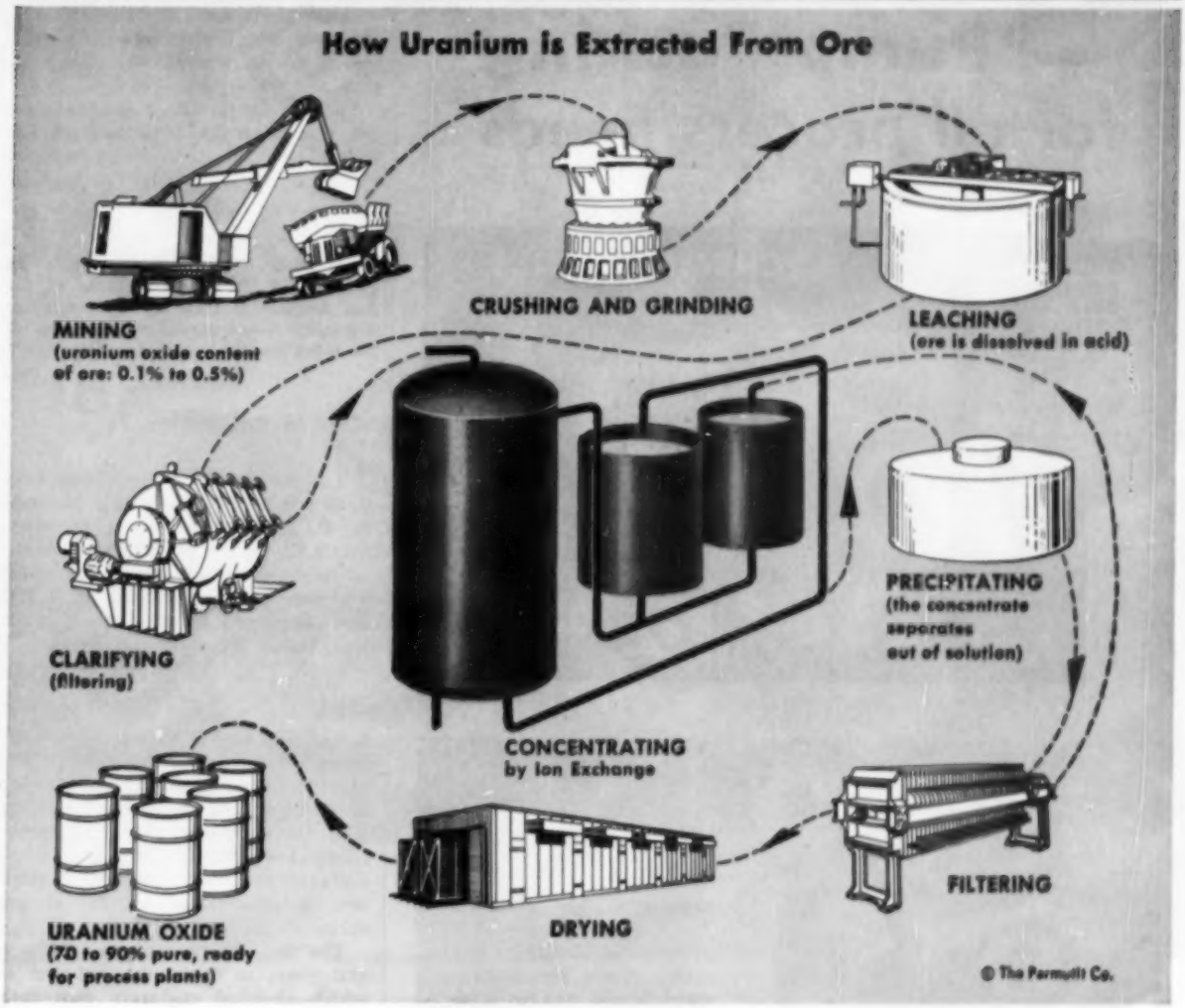
This unique combination of properties means excellent temperature control and minimum maintenance cost for oil refineries, chemical processing plants and other plants with outdoor vessels and hot piping.

Made from calcium hydrosilicate, Thermobestos is molded to size for proper fit. Its high strength makes it particularly adaptable for time-saving shop prefabrication of fittings and bends. Furnished in large sections, Thermobestos is easy to apply. It reduces the number of joints. In pipe insulation form, it comes in a complete selection of sizes up to 24" x 3" half-sections. Also available in 6" x 36" and 12" x 36" blocks in a full range of thicknesses. For further information write to Johns-Manville, Box 60, New York 16, N.Y. In Canada, Port Credit, Ontario.

Johns-Manville *first-in* **INSULATION**

MATERIALS · ENGINEERING · APPLICATION

PROCESSES: Ion exchange "swaps" chemicals in solution at high speed . . . purifies, recovers, concentrates, separates. An example:



Ion Exchange Cuts Uranium Costs

One reason uranium is costly is because it's spread so thin. Even a ton of good ore contains only 10 lb. of uranium oxide. And when that ton of ore is dissolved, its 10 lb. of uranium is hidden in *5 tons* of leach solution!

• **Solutions that dilute** would be almost too expensive to handle if it weren't for the ability of ion exchange to pick out "the needle in the haystack." Take the above example . . . ion exchange-precipitation takes the 10 lb. of uranium out of the 10,000 lb. of leach solution in one simple step...then delivers it in as little as 12 lb. of concentrate! It also discards other elements that generally stick close to uranium . . . eliminating special up-grading steps. The results: *more* uranium per ton of ore and at a lower cost than by former methods . . . and *higher grade* uranium that cuts subsequent refining costs.

• **That's why Permutit** ion exchange is at work at African, Canadian and U. S. uranium mines.

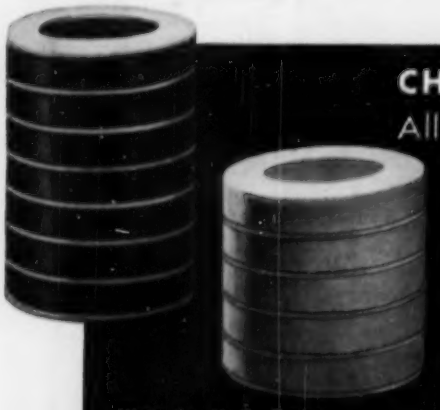
• **This compact process** also concentrates metals from industrial wastes. For example, it recovers valuable chromium from exhausted plating baths and rinse waters and, at the same time, eliminates a tough and costly waste disposal problem. It recovers copper and zinc from rayon wastes. It also removes unwanted minerals and other impurities from process and boiler feed water, chemicals, sugar solutions and hundreds of other products.

• **We'll be glad** to look into ways it might apply to your process. Write to The Permutit Company, Dept. CEP-4 330 W. 42nd St., New York 36, N. Y.

PERMUTIT®
rhymes with "compute it"

ION EXCHANGE for Water Conditioning
Chemical Processing • Industrial Waste Treatment

Centrifugal Pump Packing for all process needs



CHEMISEAL . . . for All-Chemical Service

Made in two types—pure duPont' TEFLON,* No. 711-D, and TEFLON with Graphite, No. 711-G.

Handle all types of corrosives including hazardous chemicals. Also ideal for non-contaminating service in the manufacture of pharmaceuticals, biologicals, foods, etc.

Outlast other type packings in chemical service, many times over.

Write for U. S. Gasket Catalog No. FP-1255 on Engineered Valve and Pump Packings.

*du Pont Trademark

BELMONT "Centrifugal" for General Service

Belmont "Centrifugal" Type 754-P, is a "custom-made" packing for centrifugal and rotary pumps that protects pump shafts against scoring, wear.

Lubrication that is impregnated into every strand of asbestos yarn, and graphiting that is braided into the structure for life—allows shaft free motion. Keeps packing live, smooth-running.

Write for Belmont Catalog on this and other "Custom-made for the Service" Packings.

Ask your U. S. Gasket-Belmont Distributor or write for literature.

United States Gasket Company
Camden 1, New Jersey

The Belmont Packing & Rubber Co.
Butler & Sepviva Sts., Phila. 37, Pa.

U.S. GASKET • BELMONT PACKING

Letters to the Editor

(*Continued from page* 12)

California Snapshots

Enclosed are some prints and films of snapshots that I took during the symposium "A.B.C.'s of Machine Computation" and the trip No. 2 to U.C.L.A.

Each of the prints is numbered on the back and the accompanying list describes the subject of the photograph.

E. R. McCartney
Los Angeles, California

Member McCartney's gesture in providing C.E.P. with pictures of the Los Angeles meeting is very much appreciated. Readers will see samples of his work on page 84 of this issue.

Editor

More on Orientation Films

Last month C.E.P. ran a letter from C. E. Dryden which carried a comment by F. J. Van Antwerpen, Secretary, A.I.Ch.E., on the possibility of chemical engineering educational films for freshmen engineers. Herewith is further comment by Robert York, chairman, Public Relations Committee.

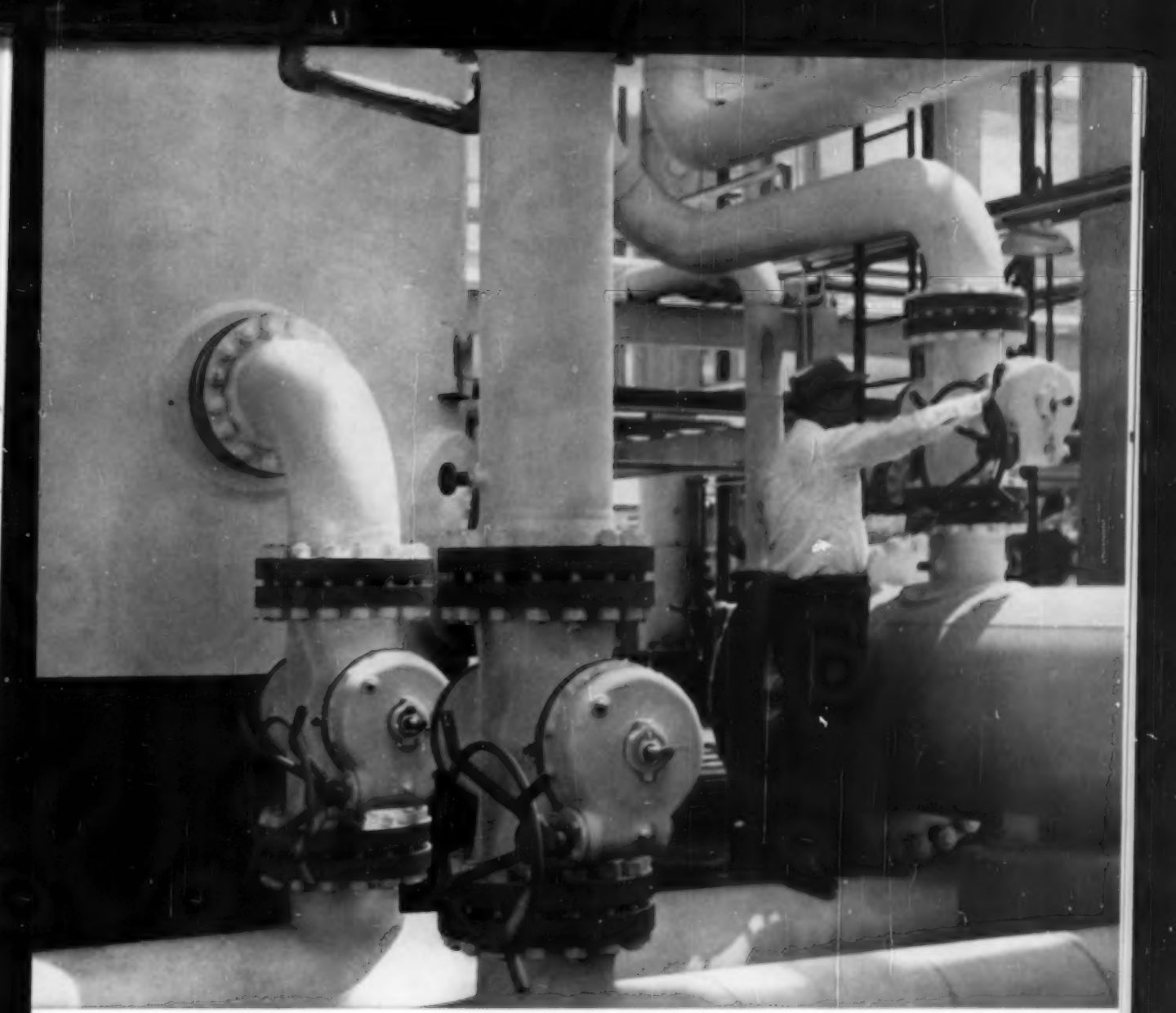
Editor

The A.I.Ch.E. has been cautious to follow a policy of giving advice and counsel for vocational guidance and definitely avoiding any attempts to sell or proselyte high school seniors and college freshmen towards a career in chemical engineering. Its policy is essentially one to work jointly with all engineering groups and let the student decide on his own career.

The A.I.Ch.E. has planned for several years to depict the activities in which chemical engineers earn their livelihood and serve the public. The Public Relations Committee has had this as an active project for over five years. Unfortunately, the costs are estimated between 8 and 50 thousand dollars and are prohibitive at present and perhaps for the next couple of years. Other national committees such as the Educational Projects Committee and the Vocational Guidance Committee are laying plans for making a film or at least for incorporating their points of view in an over-all Public Relations film.

Dr. Dryden offers the suggestion that the management of chemical and petroleum companies contribute toward the preparation of a career-type movie. Some companies have made films for their own use; others prefer to contribute jointly through the Manufacturing Chemists' Association.

(*Continued on page* 22)



Why gamble your profits?

Valves are a major investment. Why gamble your profits on risky valves when you can buy the best at a price that is often lower than ordinary valves? Your valve investments are secure when you specify Rockwell-Nordstrom valves because *pressurized lubrication* assures economy and dependability in these three important ways:

1. Leakproof Sealing . . . eliminates uncertain, "forced" metal-to-metal seating.

2. Longer Life . . . lubricant stops trouble before it starts . . . slashes repair, maintenance and down time costs.

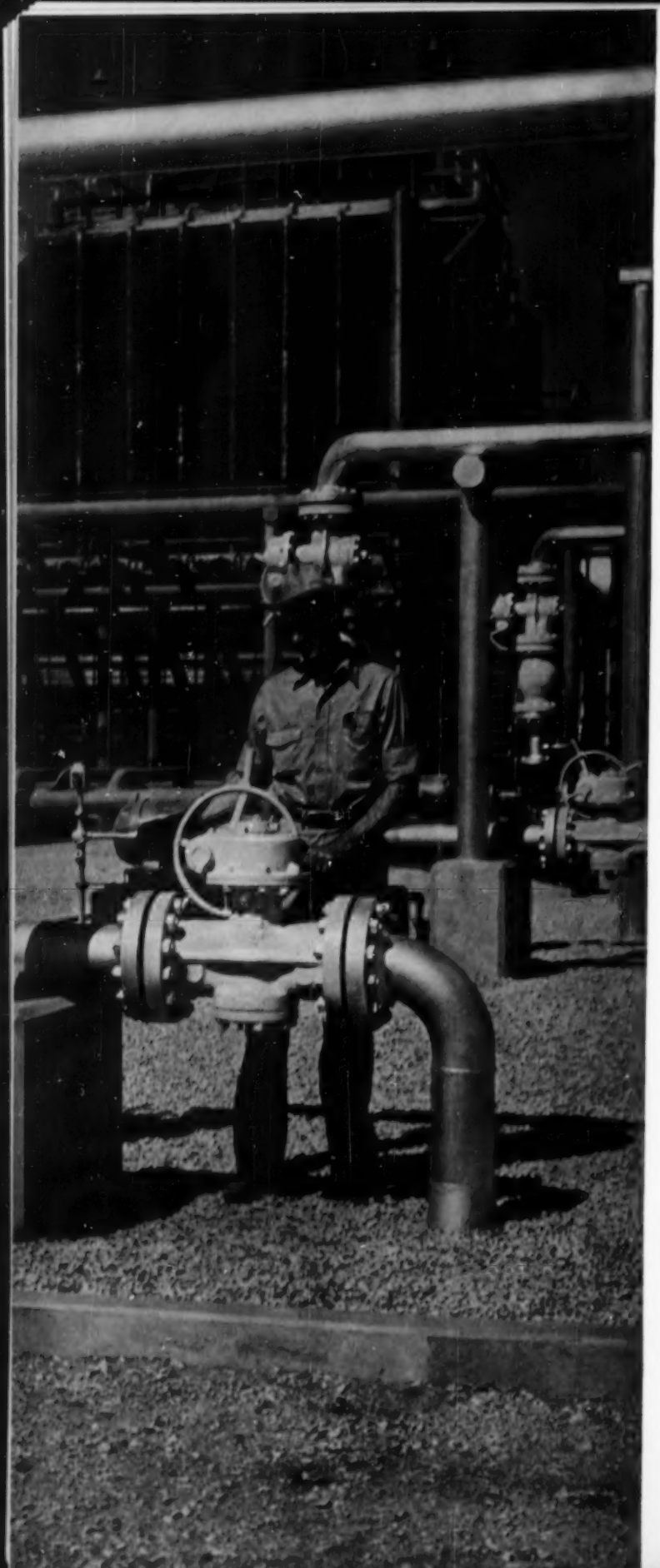
3. Instant Operation . . . lubricant "cushions" plug for smooth, quarter-turn operation.

Forty years of lubricated plug valve leadership by the original and world's largest manufacturer is your assurance of economy and trouble-free dependability when you specify Rockwell-Nordstrom valves. Rockwell Manufacturing Company, Pittsburgh 8, Pa.

ROCKWELL-Nordstrom **VALVES**

Lubricant Sealed for Positive Shut-off

40th Year *of lubricated plug valve leadership*



How to handle tough services

Many services (like high-velocity gas service) eat the heart right out of ordinary valves. Metal-to-metal seating soon becomes pitted or scored and the valve won't hold. The result—expensive reseating, down time and snarled production schedules.

In Rockwell-Nordstrom valves a thin, tough film of pressurized lubricant between the plug and the valve body forms a *continuous* and *dependable* seal at any pressure on any service. The lubricant also protects against corrosive-erosive material and eliminates metal-to-metal friction for longer service life at lowest cost.

Rockwell-Nordstrom, *the original and most complete line* of lubricated plug valves are available in steel, semi-steel, stainless steel and special alloys for a complete range of pressures and temperatures. For more information, write: Rockwell Manufacturing Company, Pittsburgh 8, Pennsylvania.

Available at leading suppliers . . . everywhere.

ROCKWELL-
Nordstrom
VALVES

Lubricant Sealed for Positive Shut-off

40th Year
of lubricated plug valve leadership

VINYL FOAM

Vinyl foam is used in this auto arm rest.

Another new era of improved products aided by Votator® PROCESSING APPARATUS

Vinyl foam, now out of the pilot plant and into mass production, is bringing important advantages to many products. Here is another great achievement of American industry in which engineers of Girdler's Votator and Thermex Divisions have made vital contributions.

The flow chart shows the basic elements of a system for the continuous production of polyvinyl chloride foam sheeting. This versatile system, in which the Elastomer Process† is widely and advantageously employed, makes possible the use of many resins and plasticizers for the manufacture of open-cell flexible vinyl foam in a broad range of resiliences. It is used for both flat stock and molded articles.

In this system, VOTATOR* Processing Apparatus mixes and cools the vinyl on a continuous basis and delivers it at the right temperature and consistency, ready for spraying or molding.

Many processing functions are performed with VOTATOR Heat Transfer and Mixing Apparatus. Find out how it can help *you* in the development of *new* products and in the *improvement* of existing products. Call our nearest office or write for a copy of the Votator Data Book.

†Licensed by Elastomer Chemical Corporation

*VOTATOR—Trade-Mark Reg. U. S. Pat. Off.

the GIRDLER Company

A DIVISION OF NATIONAL CYLINDER GAS COMPANY

LOUISVILLE 1, KENTUCKY

VOTATOR DIVISION: New York, Atlanta, Chicago, San Francisco
GAS PROCESSES DIVISION: New York, San Francisco. IN CANADA: Girdler Corporation of Canada Limited, Toronto

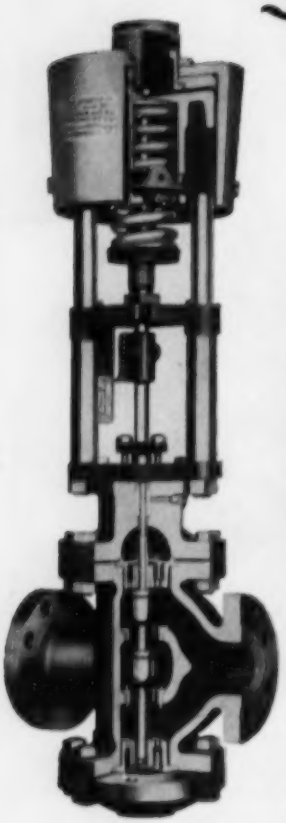
FOR FLUID CONTROL...

THE NEW FOSTER

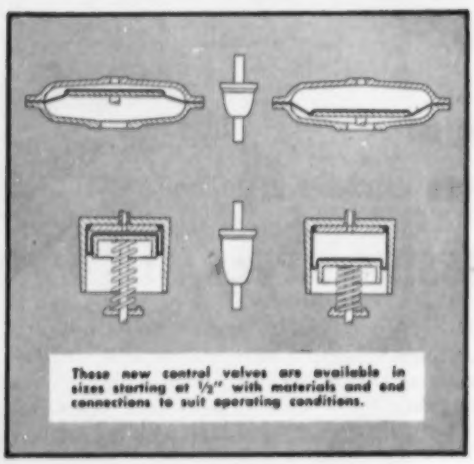
CONTROL VALVE WITH

ISOFORCE ACTUATOR

Gives you greater sensitivity



... because the Foster Bellofram construction gives you longer travel than other diaphragm actuated types — allowing for increase in length of main valve for more sensitive throttling action.



These new control valves are available in sizes starting at ½" with materials and end connections to suit operating conditions.

For complete technical information, ask for Bulletin CV-1

FOSTER AUTOMATIC VALVES

FOSTER ENGINEERING COMPANY

835 LEHIGH AVENUE, UNION, N. J.

- AUTOMATIC VALVES
- CONTROL VALVES
- SAFETY VALVES
- FLOW TUBES

Letters to the Editor

(*Continued from page* 18)

Dr. Dryden's suggestion is appropriate for good public relations. We hope to resolve some of our problems and proceed with our plans for a movie film as a project of the Public Relations Committee.

Robert York
Chairman
Public Relations Committee
St. Louis, Missouri

A Costly Explanation

In the January issue of Chemical Engineering Progress there was under the Industrial News section a note on "Liquid Metal Reactor, A Commercial Possibility," pages 34 and 38. In this note it was stated that the cost of electrical energy from this reactor would be 0.071 cents/KWh, and for four such reactors the cost would come down to 0.065 cents/KWh.

These cost prices of electrical energy are so low that one suspects a typographical error. If this is the case, I should like very much to know the correct costs.

Hallvard Nilsen
Sarpsborg, Norway

A slip of a decimal point can surely create cheap power. It should, of course, have read 0.71 and 0.65, respectively.

Editor

Noted and Quoted

Engineers Cannot Take Over the Entire Job

We learn . . . that the cosy generalizations we made about the backwardness of Russian education were part of the same wool of self-deception. As the Iron Curtain goes up one of the first things we see is that the Soviet Union has virtually been turned into an educational forcing-house for the production of physicists and engineers. The U. S. Atomic Energy Commission has before it a report showing that we are being badly outstripped in the training of scientific personnel.

The multiple threat before the American people cannot be adequately met on the purely competitive level. It is not

(*Continued on page* 28)

Like to join this session on atomic-powered ships?

This is a working session of some of the country's best scientific and engineering minds. Their assignment: develop, design and construct atomic power plants for a fleet of ships. Where are they? At Bettis Plant, Pittsburgh, operated by Westinghouse for the AEC. This is the largest design and engineering center for atomic power plants in the country. Here the power plants for an atomic fleet are actually being designed and built.

You can join them if you are a competent chemist, chemical engineer or mechanical engineer. The work is fascinating—anything but routine—because so many of the important things being done at Bettis are being done for the first time.

Activity at Bettis Plant is expanding because more power reactors are being built here than at any other place.

Atomic experience is *not* required. Write for a descriptive brochure describing opportunities in your field. Be sure to indicate your specific interests. Mr. A. M. Johnston, Westinghouse Bettis Plant, P. O. Box 1468, Dept. A-17, Pittsburgh 30, Pa.

Westinghouse

BETTIS PLANT

First in atomic power

IMPROVED

The Cenco-Meinzer Industrial Sieve Shaker

Finished in light gray hammertone . . . equipped with 1/15 hp motor . . . 115 volt, 50/60 cycles, AC or DC. Price, without sieves $173.00

* for mechanical analysis of industrial materials . . . for sieving heavy mineral powders, light organic samples, fine pharmaceutical powders.
* holds six standard 8-inch or 5-inch sieves.
* will separate a mixture, by particle size, into six components in one operation.
* provides quick, accurate separation without caking or plugging sieves.
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DESIGNING ENGINEERS AND CONSTRUCTORS

LUMMUS

FOR THE PETROLEUM AND CHEMICAL INDUSTRIES

385 MADISON AVENUE, NEW YORK 17, NEW YORK

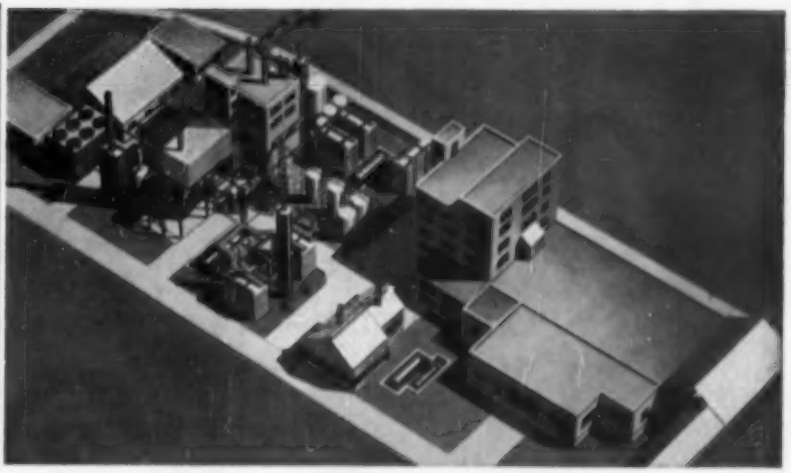
Lummus-Built Plant Will Double Phthalic Capacity For Pittsburgh Coke & Chemical

Paint and Plastics Producers to Benefit From Expansion

To double the phthalic anhydride capacity of Pittsburgh Coke and Chemical Company's Coal Chemicals Division, The Lummus Company is engineering and constructing a $3,000,000 plant on Neville Island in the Ohio River below Pittsburgh. The new plant, to be completed by Fall 1956, is a further step in Pittsburgh Coke's chemical expansion.

This second installation is being built because plasticizer and alkyd resin manufacturers need more phthalic. Since 1949, vinyl plastics consumption has risen 100%; alkyd resin paints 50%; polyester plastics 400%. Phthalic, as a basic raw material for these industries, is in ever-increasing demand. Increased phthalic consumption by Pittsburgh Coke and Chemical's own Plasticizer Division has also been a major factor in the company's planning.

As a result of its long chemical experience, Lummus is well equipped to carry out this project for the manufacture of phthalic. The new facilities will incorporate many improvements in production efficiency and product purity.



Artist's conception of expanded facilities.

Other current chemical projects at Lummus include ammonia and ammonia products installations, a vinyl acetate unit and acetylene derivatives facilities. And our books show hundreds of completed plants for a wide range of products from ethylene through butadiene.

When you plan your next plant, call on Lummus—designing engineers and constructors for the petroleum and chemical industries.

The Lummus Company, 385 Madison Avenue, New York 17, N. Y. **Engineering and Sales Offices:** New York, Houston, Montreal, London, Paris, The Hague, Bombay. **Sales Offices:** Chicago, Caracas. **Heat Exchanger Plant:** Honesdale, Pennsylvania. **Fabricated Piping Plant:** East Chicago, Indiana.

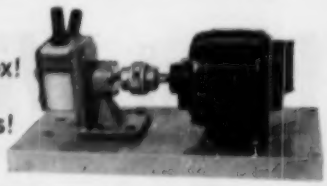
THE PROBLEM:

PUMPING SULPHURIC ACID

THE SOLUTION:

VANTON PLASTIC PUMP

No stuffing box!
No gasket!
No shaft seals!



A leading producer of welding gas had the problem of transferring concentrated sulphuric acid (93%) from storage to process tanks. The pump had to operate 6 to 10 hours daily and deliver 10 gpm against a 15 ft. head. The answer was found in a Vanton "flex-i-liner" pump, model PX60, with its polyethylene body block and hypalon flexible liner.

If you're troubled with pumping corrosive or abrasive liquids and slurries, get the facts on the Vanton "flex-i-liner."

Catalog 56-S on request.

VANTON
PUMP & EQUIPMENT CORP.
201 Sweetland Ave. Hillside, N. J.
division of Cooper Alloy Corporation

The Problem:

PUMPING HYDROCHLORIC ACID

The Solution:

VANTON PLASTIC PUMP

No stuffing box!
No gasket!
No shaft seals!

A large producer of industrial chemicals, seeking a portable carboy transfer unit for pumping concentrated HCL, solved his problem with a self priming Vanton "flex-i-liner" pump, Model XB-P30 (5 GPM). The polyethylene body block and Hypalon "flex-i-liner" are the only materials in contact with the fluid, and the design eliminates stuffing boxes and shaft seals. Pump and base are mounted on casters for portability. Maintenance has been reduced to annual replacement of the inexpensive "flex-i-liner".

For pumping corrosive fluids, abrasive slurries, and fluids which require no contamination, Vanton is a natural.

Catalog 56-H on request.

VANTON
PUMP & EQUIPMENT CORP.
201 Sweetland Ave. Hillside, N. J.
division of Cooper Alloy Corporation

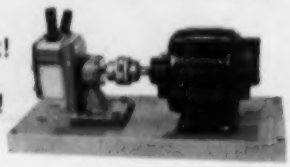
The Problem:

PUMPING FERRIC CHLORIDE

The Solution:

VANTON PLASTIC PUMP

No stuffing box!
No gasket!
No shaft seals!



A major manufacturer of electronic equipment faced the problem of transferring corrosive ferric chloride in the new Printed Circuit department to and from the etching machine, located 40 ft. from the pump unit. It was solved by using a Vanton pump, Model NX-90 (15 GPM) with Buna N body block and Natural Rubber "flex-i-liner". Since the Vanton operates equally well in either direction, a reversing switch on the motor made possible ready changes in the direction of flow.

When the problem involves corrosive or abrasive solutions or slurries, the sealess, self priming, no stuffing box Vanton is the answer.

Catalog 56-F on request.

VANTON
PUMP & EQUIPMENT CORP.
201 Sweetland Ave. Hillside, N. J.
division of Cooper Alloy Corporation

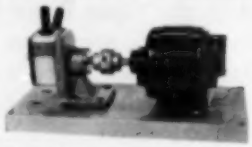
The Problem:

PUMPING ABRASIVE SLURRIES

The Solution:

VANTON PLASTIC PUMP

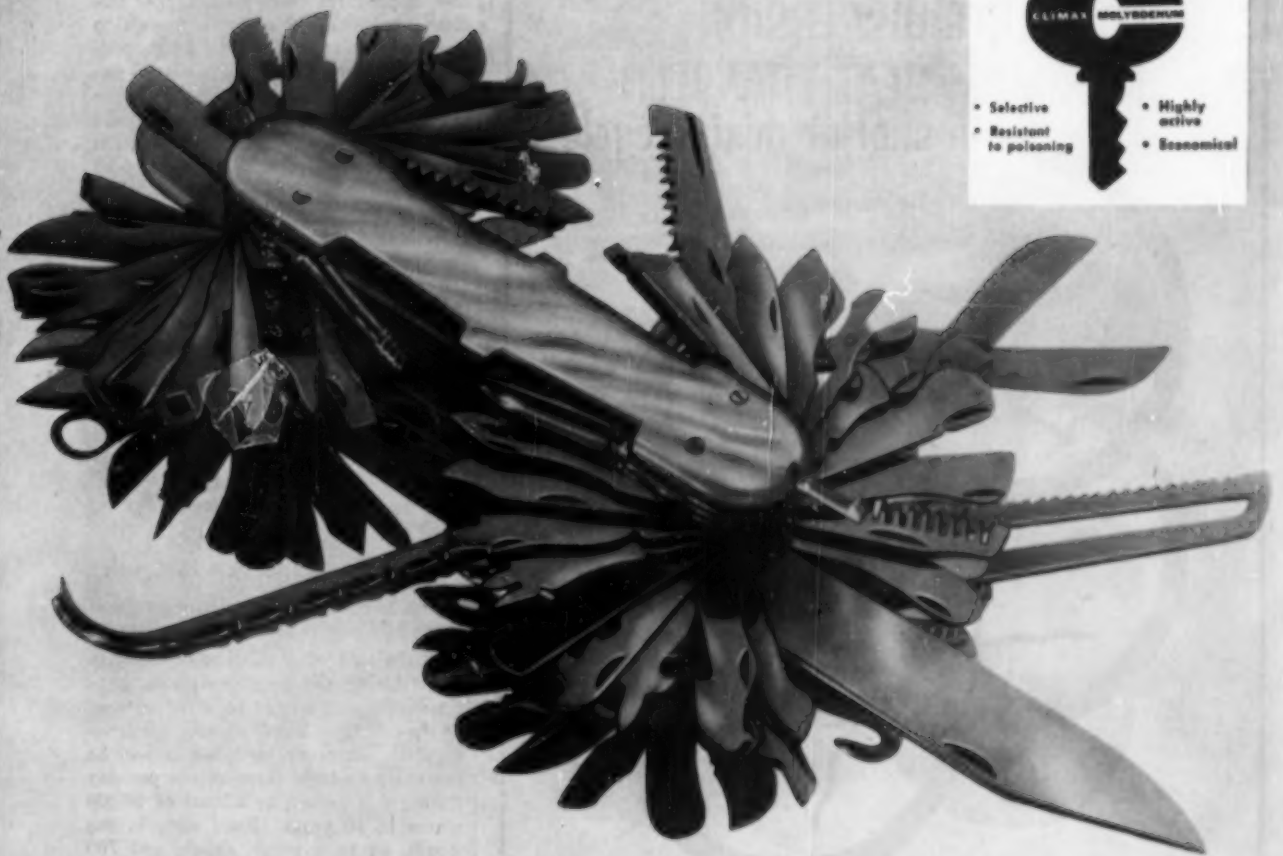
No stuffing box!
No gasket!
No shaft seals!



A foremost manufacturer of ceramic wall tiles had the problem of transferring extremely abrasive ceramic tile glaze from drums, where the glaze was mixed, to storage tanks. This heavy and extremely abrasive slurry had quickly destroyed mechanical seals and packing in ordinary pumps and rapidly wore rotating parts. A Vanton Pump Model NX-120 (20 GPM) with Buna N body block and Natural Rubber "Flex-i-liner" readily solved this problem reducing maintenance costs to a minimum.

Whether the problem be one of handling abrasive slurries, corrosive solutions, or fluids which must be maintained contamination free, investigate the use of the Vanton "Flex-i-liner" pump. Catalog 56-A on request.

VANTON
PUMP & EQUIPMENT CORP.
201 Sweetland Ave. Hillside, N. J.
division of Cooper Alloy Corporation



Moly catalysts are versatile

Because of its versatility, molybdenum is one of the most widely used catalytic elements. As a transition element, it has the incomplete inner shell of electrons needed for catalytic activity. Ease of transition from one to another of its six valence states allows it to function readily as an electron acceptor or donor. It forms a variety of compounds in all valence states, most of them resistant to common catalytic poisons. Commercially, molybdenum catalysts are used in seven types of reactions: oxidation, hydrogenation, dehydrogenation, isomerization, cyclization, chlorination and condensation. Promising results have been obtained in dehydration, polymerization and alkylation. For complete data write Department 25, Climax Molybdenum Company, 500 Fifth Ave., New York 36, N. Y. for our bulletin, "Molybdenum Catalysts for Industrial Applications."

CLIMAX MOLYBDENUM

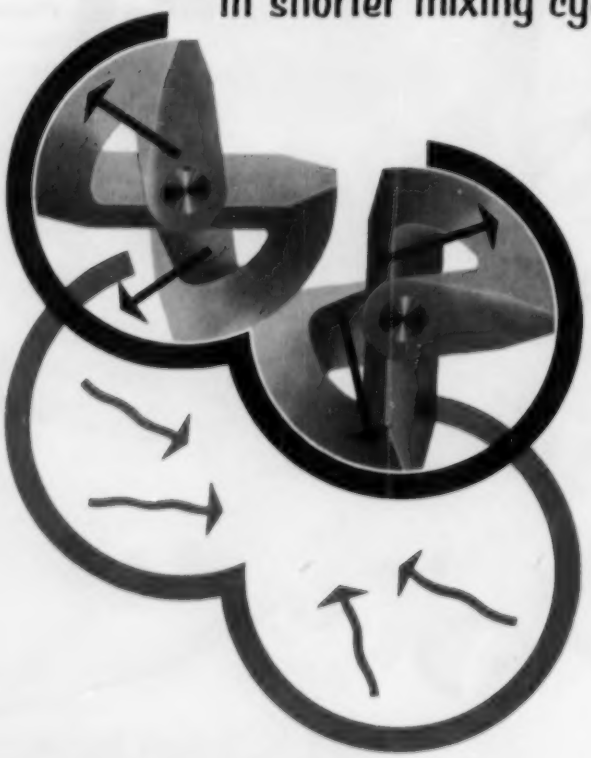
Courtesy of Hoffritz for Cutlery, 331 Madison Avenue, New York

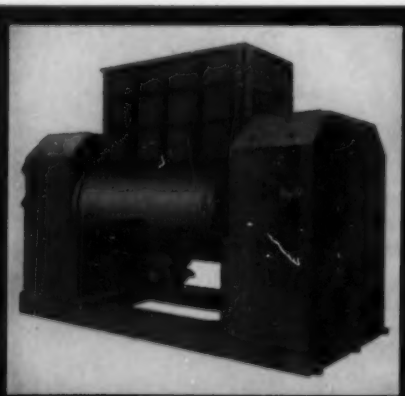
From this unique bowl

...COMPLETE DISPERSION

...MAXIMUM HEAT TRANSFER

in shorter mixing cycle





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CORPORATION

The unique shape of this mixer bowl presents a greater ratio of heated surface to the mix. Close clearances between the mixer arms and shell eliminate build-up of materials, facilitating heat transfer.

Overlapping sigma-arm mixing action exposes new surfaces and breaks down the entire mass with each rotation, eliminating peak loads and producing a homogenous mix in a short mixing cycle.

Available in capacities up to 750 gallons.

BAKERY-CHEMICAL DIVISION, York, Pennsylvania

Noted and Quoted

(Continued from page 22)

enough to speed up our own ballistic missile program or to make bigger nuclear explosions. Nor is it enough to say that we must devise a crash program for turning out scientists and engineers by the tens of thousands. The defense of America rests today, as it did all along, not on arms alone but on what we stand for in the world. The first front is the moral front. What other people see when they look at America; the kind of hope that comes to life at the mention of our name; the crisp conception of justice inside America and in our dealings as a nation; any ideas we may have about a pooling of sovereignty in the creation of effective world law—all this is what counts. Military preparedness without it is motion without direction.

Norman Cousins
"The High Cost of Superiority"
Saturday Review

Phenomenal Expansion in South

The South is ready to finance a great part of its own industrial expansion. . . .

If the rate of expansion of industry . . . during the past few years continues, the area should have 30 per cent of the country's manufacturing facilities by 1965. In order to do so, it will be necessary to build three plants per day during this period, or a total of 10,000 plants in 10 years. Each state in the South, on an average, should add 700 plants to its industrial potential by 1965.

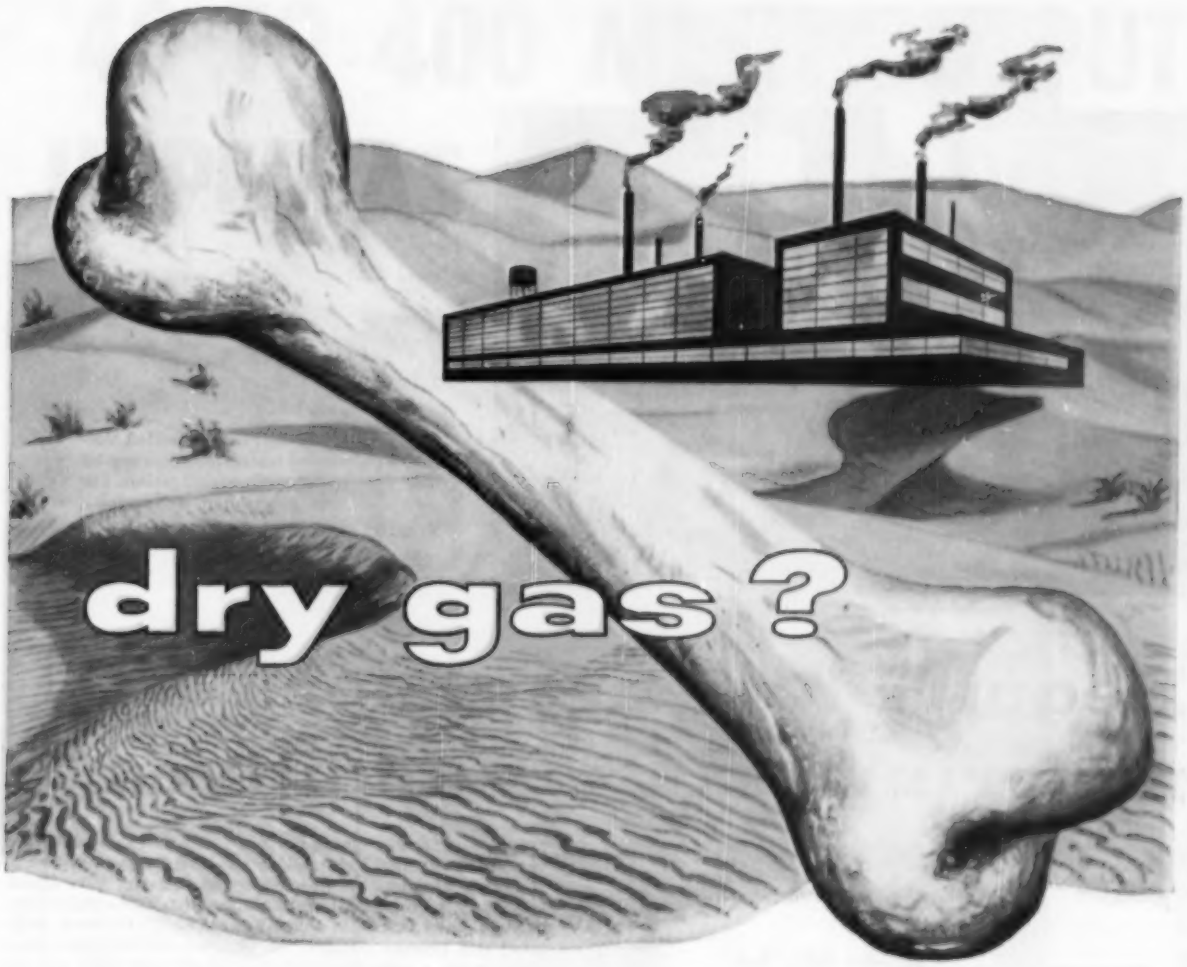
Frank J. Soday
In address before annual meeting
Alabama Bankers Association

Project at M.I.T. Combustion Lab.

Another investigation is attempting to evaluate the absolute rate of the chemical reaction in gaseous combustion. The rate of mixing of the vapor fuel and the air has been increased by the use of jets at sonic velocity until energy releases of 300,000,000 B.t.u./hr. cu.ft. have been obtained, indicating that the basic chemical reaction has a rate at least this large. An understanding of the mechanism and rate of the chemical reaction involved will contribute to evaluating the limitations on high output combustion chambers of the type employed in ramjets.

Report of the Dean
School of Engineering
Massachusetts Institute
of Technology

(Marginal Notes on page 32)

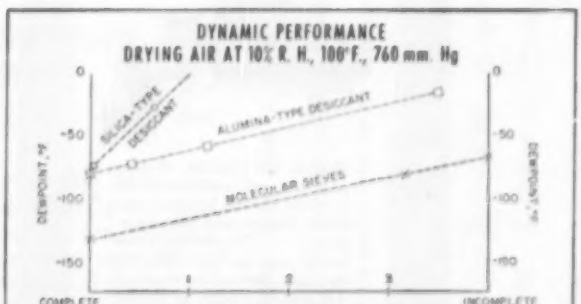


Now you can dry gases drier than dry!

LINDE Molecular Sieves can dry your gases—air, hydrogen, chemical streams—more thoroughly than any other commercial adsorbent. They will duplicate laboratory performances—*in your plant*—under normal *production* conditions.

Even though your gas stream may already be partly dried, Molecular Sieves will remove the last traces of moisture. Only a small volume of adsorbent is required. The same combination of high capacity and low dew-point is also obtained at high temperatures, up to 200°F.

This is SUPER-drying! Dynamic performance is shown in the accompanying graph. This superior performance also can be expected at higher relative humidities and at other temperatures and pressures. Of particular significance in production is the relative insensitivity of Molecular Sieves to incomplete regeneration.



For further information, write for data sheets on "Drying of Gases." Address Dept. CP-4, Linde Air Products Company, A Division of Union Carbide and Carbon Corporation, 30 East 42nd St., New York 17, N. Y.

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MOLECULAR SIEVES

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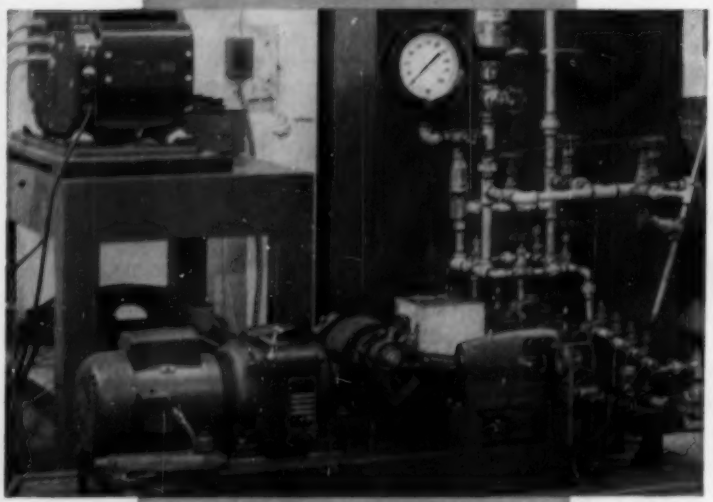
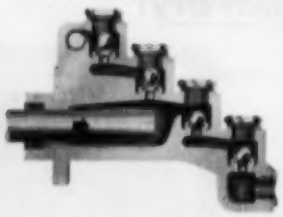


Standard motor-driven Controlled Volume Pump being tested for accuracy by independent research organization. *For details of test procedures and results, write for Technical Paper No. 55-1-1.*

Required accuracy for metering process additives

Exclusive Milton Roy STEP-VALVE LIQUID END



Double ball checks, sloping passages and absence of air pockets assure highest possible volumetric efficiency. Should a solid particle lodge under one suction ball, for example, second suction ball will seat on discharge stroke, thereby preventing fluid from being pumped into suction piping.

THE INHERENT accuracy (within ± one percent) of Milton Roy Controlled Volume Pumps can solve your chemical metering problem. As flow controllers, these units simultaneously meter and pump process fluids. As ratio controllers, they maintain a fixed relationship between additives and process streams. As final control elements they contribute to accurate regulation of pH and other process variables.

There is a Milton Roy Controlled Volume Pump or chemical feed system for practically every chemical metering need. Capacities range from 3 milliliters per hour to 45 gallons per minute, with flexible adaptations for manual or automatic control of pump capacity. Pressures up to 50,000 psi.

Write for application data contained in the bulletins listed below. One of these will probably suggest the simple, economical solution to your chemical metering problem.

Bulletin 455 "Controlled Volume Pumps in Paper Making"

Bulletin 953 "Controlled Volume Pumps in Industrial Water Treating"

Bulletin 1253 "Controlled Volume Pumps in Process Instrumentation."

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40 TO 400 MESH OUTPUT UPPED AS MUCH AS 300%

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. . . comes naturally to Sturtevant engineers. They have a tradition of success in developing dry-processing equipment and plants for more than 75 years — from the first rock emery mills to the most modern fluid jet micron-grinding equipment. If your problems include any of the processes listed in the coupon, it will pay you to investigate.

WHAT CAN A STURTEVANT AIR SEPARATOR DO IN YOUR PULVERIZING SYSTEM?

In the cement industry, Sturtevant Air Separators have a tested record of increasing mill capacities from 25 to 300% while lowering power consumption as much as 50% — when used in closed circuit with grinding mills. Maybe they can do as well for you.

Easily adaptable to your materials. Sizes of Sturtevant Air Separators range from 3 to 18 feet in diameter. They deliver fines from 40 to 400 mesh at rates as high as 100 tons per hour.

Designed to cut costs! Sturtevant Air Separators are built for a lifetime of low-downtime service. Rugged construction plus easy accessibility for quick maintenance (typified by the "OPEN-DOOR" design in other Sturtevant equipment) assures more output per machine-year. Check the coupon for more information.

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BLENDERS • GRANULATORS • CONVEYORS • ELEVATORS

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Desired capacity is:_____

Name_____ Title_____

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Please send me your bulletin on Air Separators ☐
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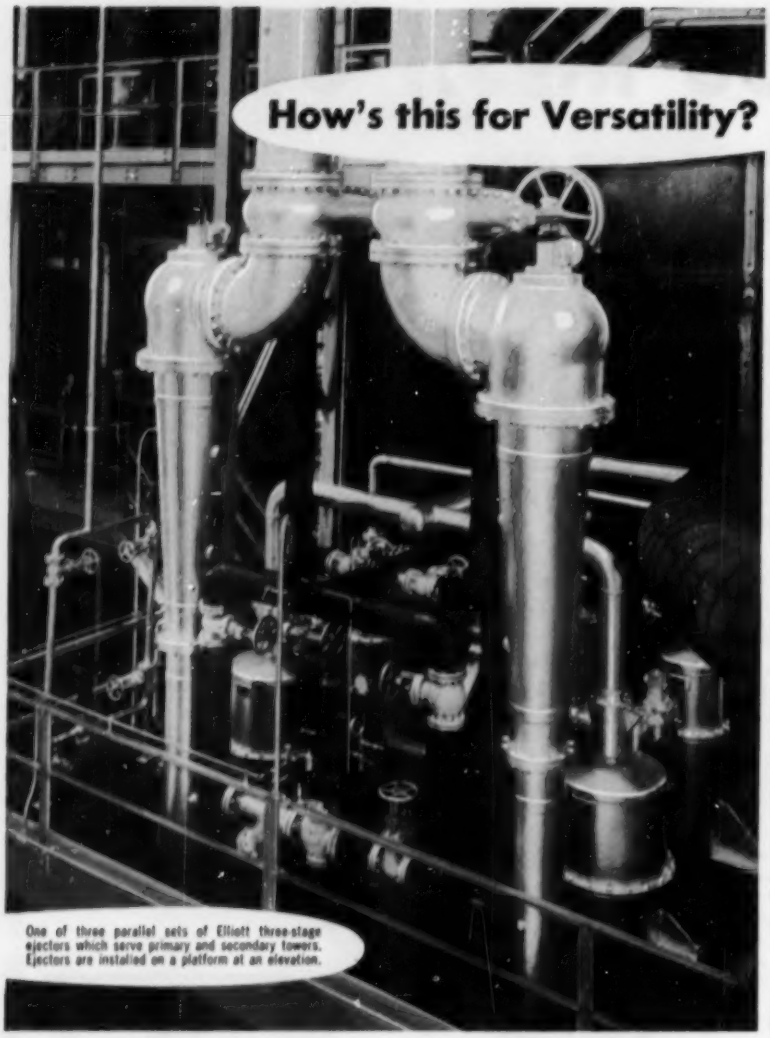
How's this for Versatility?
One of three parallel sets of Elliott three-stage ejectors which serve primary and secondary towers. Ejectors are installed on a platform at an elevation.

ELLIOTT *Steam Jet* EJECTORS

This installation in a large oil refinery called for three parallel sets of Elliott three-stage steam jet ejectors. Parallel ejectors permit one set to be shut down during reduced rates, making for greater economy in steam consumption. They operate on 100 psig steam, maintaining vacuum on both the main unit and the secondary tower. Tower pressure is controlled by recycling gases from the third-stage ejector discharge back ahead of the first stage ejector.

Whenever vacuum is required, it pays to utilize the know-how of Elliott ejector specialists. Contact your Elliott representative or write Elliott Company, Jeannette, Pa. for descriptive bulletins.

ELLIOTT Company

GS-1

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MARGINAL NOTES

Plastics Progress 1955. Edited by Phillip Morgan. Iliffe & Sons, Ltd., London and Philosophical Library, Inc., New York, 432 pages (1955) $17.50.

Reviewed by H. W. Mohrman, Director of Research, Monsanto Chemical Company, Springfield, Massachusetts.

This is the third volume to appear under the title "Plastics Progress." It consists of the full report of twenty papers presented at the British Plastics Exhibition and Convention in June, 1955. It is not a complete review of all recent developments in plastics, but covers nine major areas with one or more papers in each of the following fields: Polymer Structure and Properties—Expanded Plastics—Thermoplastics—Extrusion—Work Study and Productivity—Injection Molding—Patents—Foundry Resins and Glass Reinforced Plastics. As might be expected, papers of this nature vary widely in quality and interest and, to the American reader, many will be of most value for comparison with American developments.

One feature of English technical meetings is the tendency to fewer and longer papers with considerable formal discussion from the floor. This brings out many of the listener's experiences in the field of discussion and serves to provide further evaluation of the speaker's subject. Questions and answers are included and add valuable detail, although, in some cases, little is contributed to the main theme of the paper.

The British plastics industry, which has been responsible for the discovery of several important new polymers, has lagged behind the U. S. in processing, fabrication, and applications. This is evident in the heavy reference to American developments in almost every paper. This particularly applies to the two papers on "Work Study and Productivity," and the five papers on "Glass Reinforced Plastics," in which American practice is recognized as the spur to British developments. With the exceptions noted below, information presented will not be new to those informed on American plastics literature.

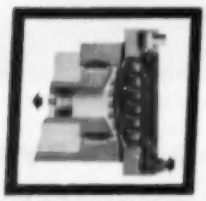
In almost every case, the papers are essentially up-to-date reviews of their subjects with original research presented only in the sections on "Extrusion" and "Injection Molding." Engineers in these fields will find the experimental data in these sections of interest. The rather long (30 pages) paper on "Fundamental Problem of Single Screw Thermoplastic Ex-

(*Continued on page 36*)

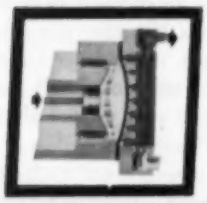
CONTROLLED-VOLUME PUMPING with

NO STUFFING BOX PROBLEMS!

The Pulsafeeder, in combining the good features of both piston and diaphragm pumps, provides an unusually dependable means of precision pumping. There is no stuffing box, hence the usual problems of maintenance and repacking associated with plunger-type metering pumps do not exist. The product being pumped is isolated from the pump's working parts by a hydraulically balanced diaphragm and is kept safe from contamination and leakage to atmosphere.



SUCTION STROKE



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Positive displacement is achieved by a piston reciprocating within an accurately sized cylinder at an established stroke length, displacing an exact volume of hydraulic oil. By means of this oil, the piston moves the diaphragm alternately backward and forward. The displacement of this diaphragm travel takes in the liquid on the suction stroke of the piston and discharges a like amount of liquid on the discharge stroke of the piston.

WRITE FOR BULLETIN 440 *with typical applications, flow charts, description and specifications of models of various capacities and constructions. Inquiry Data Sheet included from which we can make specific engineering recommendation for your processing requirement. Write Lapp Insulator Co., Inc., Process Equipment Division, 505 Wilton Street, Le Roy, N. Y.*

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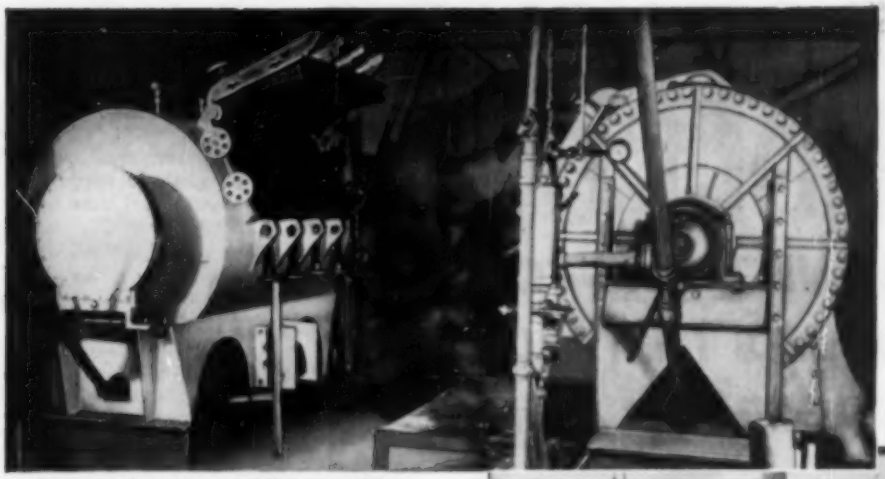

Above: Conkey Rotary Leaf Pressure Filters separating coal resins and solvents.

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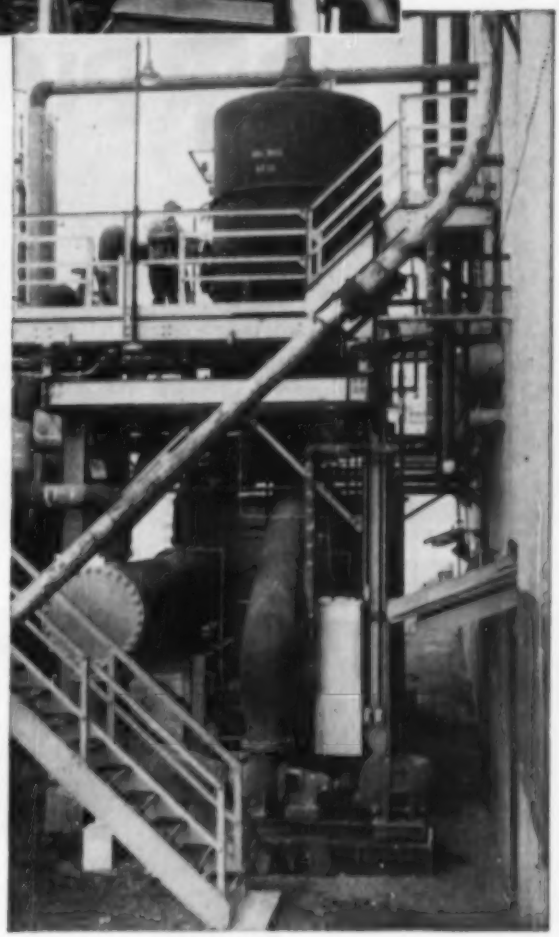

Above: Conkey Horizontal Tube Forced Circulation Evaporator.

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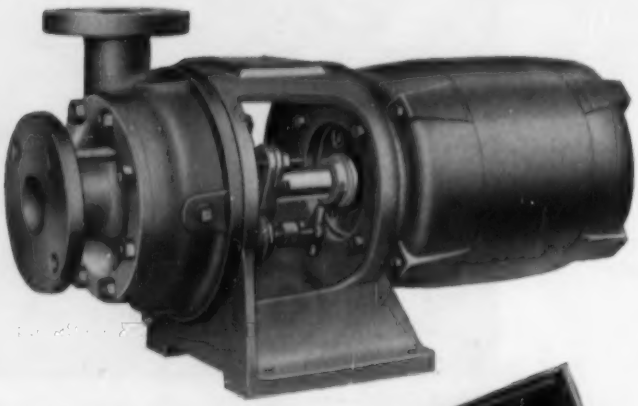
It's a fact that the efficient I-R construction often enables you to use a smaller Motorpump to do the work usually demanded of pumps of greater horsepower!

So, I-R Motorpumps reduce your costs in several ways. First of all, in original cost. Save weight and space, too. Deliver more gallons-per-minute per horsepower used . . . and cut maintenance costs as well, because Motorpumps are built for longer, trouble-free service!

If you're not familiar with the famous I-R Motorpump line you'll do well to get full details right away.



The latest catalog gives complete data needed to choose a Motorpump . . . from ¼ to 75 hp, capacities 5 to 2800 gpm, heads to 650 ft. Write to:

Ingersoll-Rand

9-366 11 Broadway, New York 4, N. Y.

MARGINAL NOTES

(Continued from page 32)

truders" analyzes possible behavior of extruders at speeds of 100 to 200 rev./min. and the possibility of adiabatic operating conditions with experimental data based principally on polyethylene. A spiral-designed test mold for evaluation of thermoplastics is described in the section on "Injection Molding." Data on commercial materials are given and good correlation of test results with commercial moldability is claimed.

Of unusual and specialized interest is the report on "Patents and the Plastics Industry." The history of British patent practice, upon which our own is based, is covered, as well as a complete description of current policies. Anyone interested in an explanation of British patent practices and a comparison with U. S. practice, will find this paper worth while.

Hydrogen Peroxide, 2 ed. W. C. Schumb, C. N. Satterfield, R. L. Wentworth. Reinhold Publishing Corporation, New York (1955), 750 pages, $16.50.

Reviewed by Ernest J. Henley, Assistant Professor, Chemical Engineering, Columbia University, New York.

This work "provides a thorough treatment of a selected area," and by focusing attention on this important . . . chemical, it should "stimulate further work in the field." The book is surprisingly readable and the topics are so well developed and integrated that, in the limit, the book could be used as a textbook of inorganic chemistry. In this respect the sections on structure and chemical properties are outstanding.

The authors have shown tasteful restraint in not attempting to cover material beyond the scope of the book. Organic peroxides, and the organic and biological chemistry of hydrogen peroxide are briefly introduced. The notation and nomenclature are unusually clear, and the single listing of letter symbols saves much valuable space.

Much previously unpublished data, largely in areas of interest chiefly to the military or to manufacturers, are included.

This latest monograph of A.C.S., the objective of which is quoted above, was born of a Navy-sponsored study at M.I.T.

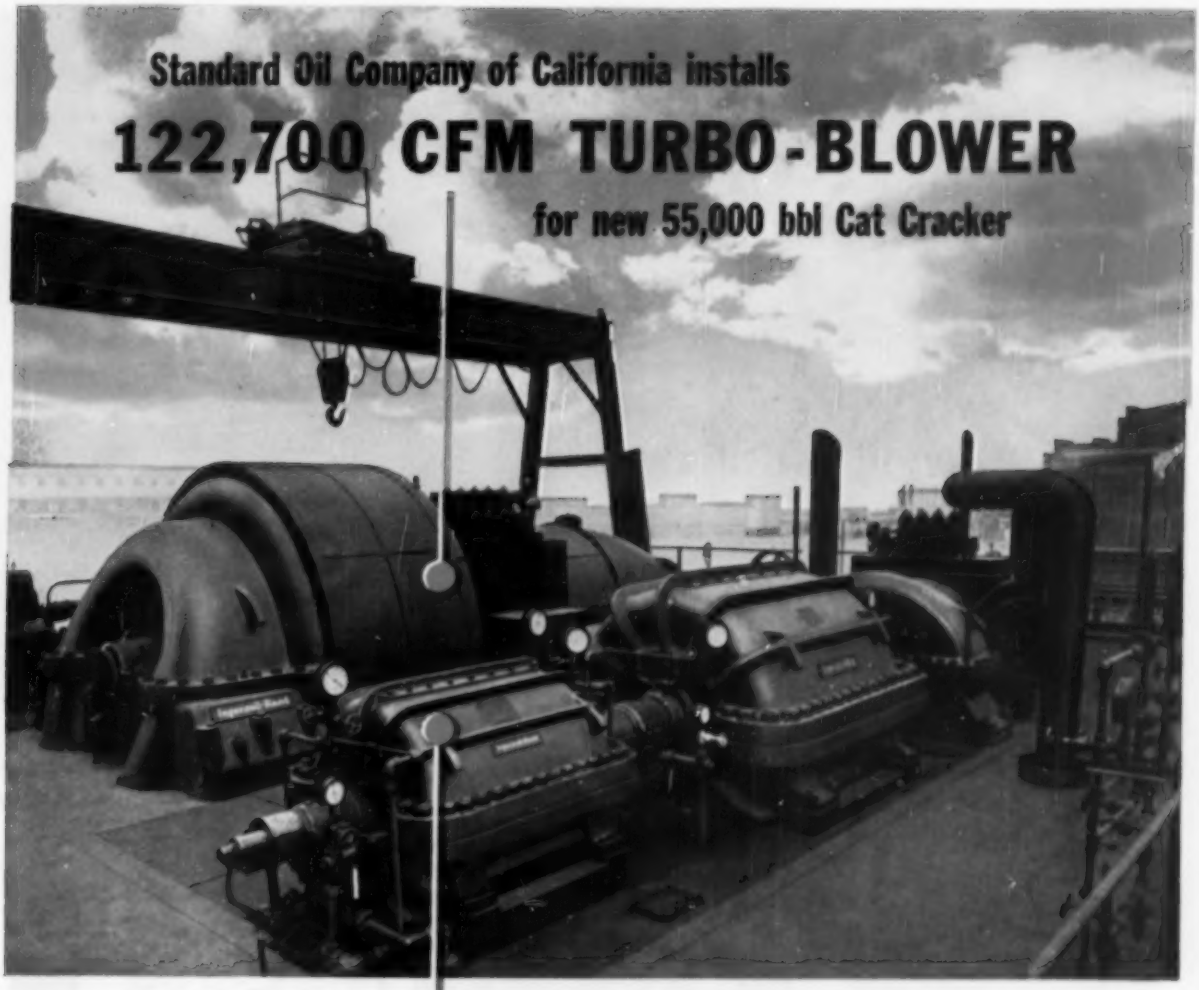
BOOKS RECEIVED

Hydraulic & Pneumatic Operation of Machines. H. C. Town. Philosophical Library, New York (1956), 192 pages, $7.50.

Standard Oil Company of California installs

122,700 CFM TURBO-BLOWER

for new 55,000 bbl Cat Cracker



Outdoor Installation at El Segundo Refinery also includes the world's largest centrifugal gas compressor in catalytic service ... both by Ingersoll-Rand

THIS INSTALLATION at Standard Oil Company of California's huge El Segundo refinery is unique in three respects.

The 122,700 cfm I-R Turbo-Blower shown in the background is one of the largest ever supplied for refinery service. It is a 3-stage unit, driven by an I-R 10,000 hp steam turbine, delivering air at 19.35 psig to the 55,000 barrel per day cat cracker.

In the foreground is the largest centrifugal refinery gas compressor in the world — a 6370 hp I-R unit consisting of two centrifugals in tandem, driven by an I-R turbine. Compressing gas from 4 psig to 205 psig, it delivers 20,800 cubic feet per minute.

The entire installation is out of doors.

Whatever *your* requirements for refinery air or gas compression, Ingersoll-Rand's unequalled experience and facilities are at your service.

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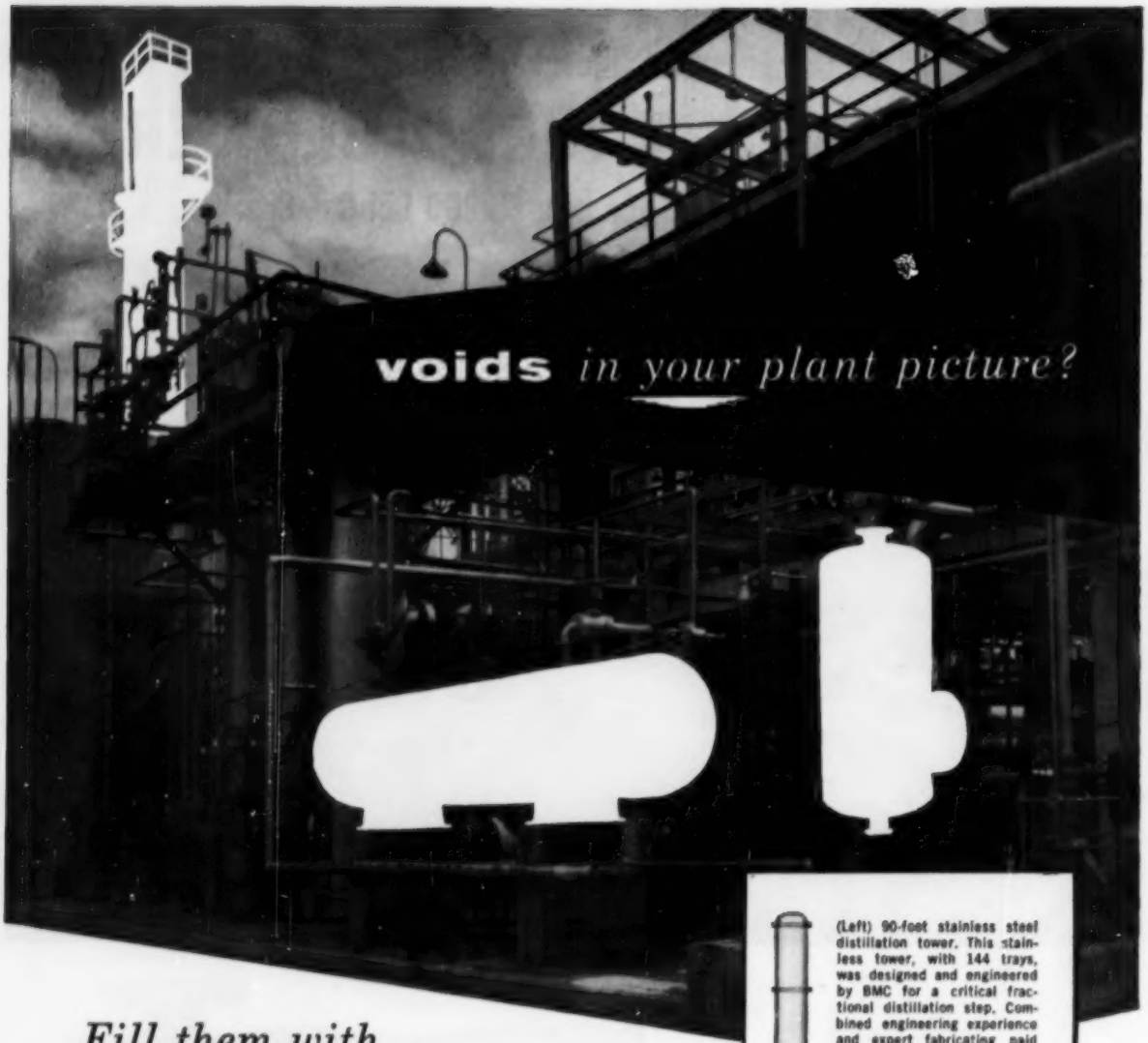

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New installation? . . plant expansion? . . modernization?

Whatever the reason you require process equipment — from a single boiling cap to a huge tower — BMC can supply it on *time*, on *quotation*, on *specification*.

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A 2000-square foot vapor condenser for alcohol purification. Engineered and fabricated to close tolerances — typical of the type of job BMC has a reputation for doing right!

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- to prevent caking
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- to extend pigments
- to aid suspension
- to reduce surface sheen

The Powder That Flows Like a Liquid—Micro-Cel, latest development of Johns-Manville Research, will greatly improve the flowability of many products.

New Johns-Manville mineral filler can help you improve products and cut costs

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Want to prevent caking? Try *Micro-Cel*—its high absorption works wonders in controlling deliquescent products.

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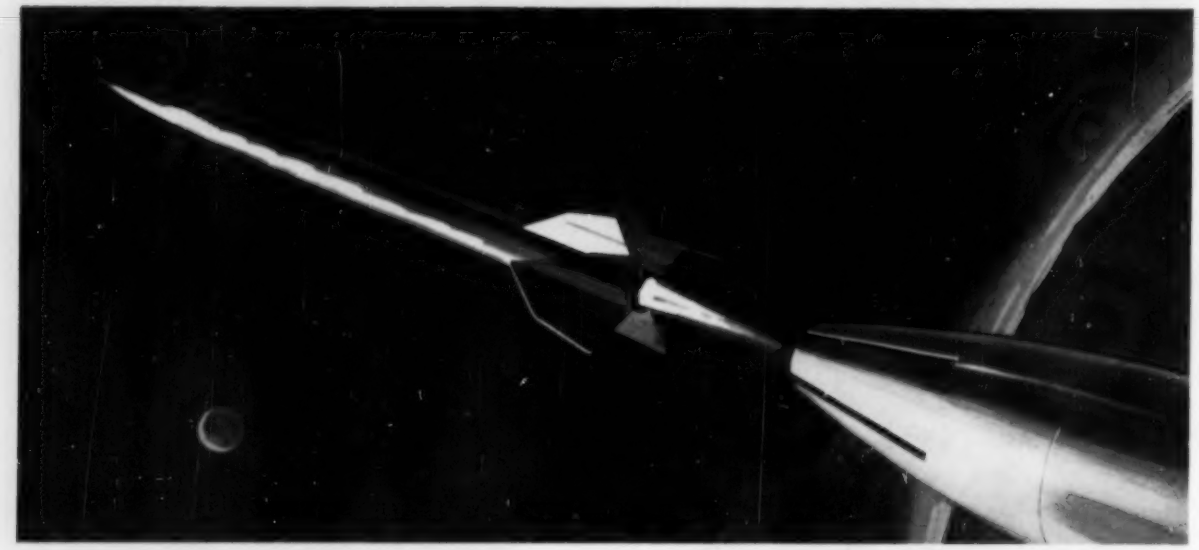
THE WORLD'S ALTITUDE RECORD of 250 miles was established by the WAC-Corporal, used as a second-stage missile fired in flight from the nose of a V-2 Rocket at White Sands in February 1949.

The "Wac" was one of a series of test rockets used by JPL in the development of the Corporal, an operational guided missile.

The technology of this two-stage rocket flight has become the foundation on which to build a globe-girdling satellite.



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NUCLEAR ENGINEERING

The success of these rockets has its roots in basic research in propellants and in the imaginative engineering design of rocket motors. Research on propellants at JPL has run the gamut of oxidizers such as nitric acid, hydrogen peroxide, and the pioneer studies of liquid fluorine. Current interest in many unusual fuels, hydrazine for example, stems directly from JPL work of ten years ago.

The Laboratory's work in propellants is of basic scientific interest and is published in professional journals. Precise redetermination of the heat of dissociation of fluorine, studies of the thermodynamics of the nitric acid family and basic research in combustion are all examples of our many continuing interests.

This work in liquid propellants is paralleled by comparable efforts related to solid propellants, materials and metallurgy.

On the engineering side, studies to improve the design of rocket motors able to handle unusual combustion and heat transfer requirements and the design of auxiliary chemical power units are in progress.

These important experiences provide a natural and firm foundation for our current interest in nuclear propulsion.

We need qualified new people for such activities. If you enjoy the challenging atmosphere of new research, write us today. Please outline your technical interests, qualifications and experience.

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Clarity Measurements in Filtration

by Paul W. Leppla, *Technical Director*

Filtration efficiency is usually measured in terms of flowrate and clarity. Flowrate is readily measured in most plants; however, clarity measurements involve the most difficult aspects of filtration technology. Consequently most industries rely upon visual evaluation of filtrate clarity, which is only semi-quantitative at best and occasionally is purely subjective.

Critical evaluation of filtrate clarity requires instrumental measurement. A number of satisfactory instruments of U.S. manufacture are available. Some measure transmitted light, a questionable technique since few of these instruments discriminate between bleaching of soluble color and the removal of suspended particulates. The measurement of Tyndall or scattered light is much preferred.

Too, the problem of absolute standards is not yet resolved, resulting in confusion on clarity measurements from one laboratory to another. One instrument company has available a series of calibrated standards, which are claimed to be stable, and at least one technical society is working on the development of absolute reference standards so that identical measurements will be possible in different laboratories.

Under these circumstances, evaluating a series of diatomite filteraids is extremely difficult. While Filteraid A may have 90% of the clarification efficiency of Filteraid B in a raw sugar solution, the relative rating in a pectin system may be only 60%. Moreover, the relative clarification of two filteraids with respect to the same liquid may change markedly depending upon the conditions of the test.

Because of the many variables involved which can influence results to an enormous degree, it is imperative that comparative tests duplicate, as nearly as possible, actual plant conditions. Since often this is difficult, many plants rely on the wealth of experience available to them from a leading supplier in this extremely complex field, experience covering many types of liquors, filters and operating conditions.

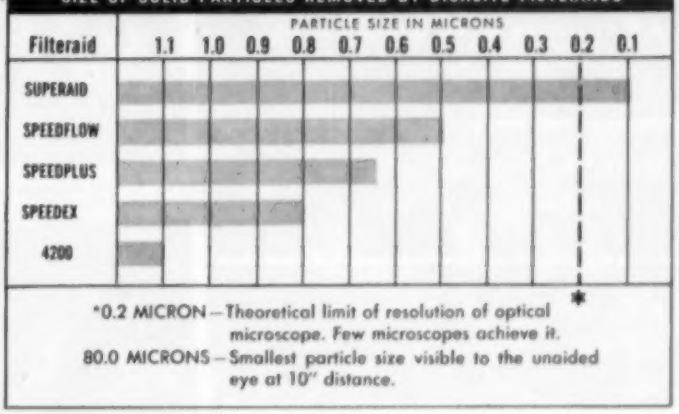
The chart in the accompanying advertisement illustrates a significant step forward in this difficult field recently achieved in the Dicalite laboratory. While it is possible to calculate the average pore size of a filter cake, our scientists have known for some time that particles much smaller than the calculated pore diameter are readily retained by diatomite filteraids. By carefully preparing suspensions of uniformly sized particles in the 1-10 micron range, and conducting laboratory filtration tests under carefully controlled conditions, they were able to determine exactly what size particles can be removed by each of the grades of Dicalite filteraids.

We believe that this type of information, never before published, is important to you, as a user of filteraids.

...With a DICALITE Filteraid

you can filter out particles so small you can't see them with a microscope!

SIZE OF SOLID PARTICLES REMOVED BY DICALITE FILTERAIDS



*0.2 MICRON – Theoretical limit of resolution of optical microscope. Few microscopes achieve it.

80.0 MICRONS – Smallest particle size visible to the unaided eye at 10" distance.

These figures, established in recent Dicalite laboratory tests, are, we believe, the first *accurate* figures ever published on the actual sizes of solids removed by different grades of diatomaceous filteraids. And the dependable uniformity of Dicalite filteraids, in all grades, assures you the same reliable performance, filter run after filter run, on all types of particulates, even gelatinous or slimy. The significance of these figures in pointing the way to the development of maximum filteraid performance can hardly be over-stated. They are one more evidence of Dicalite's leadership in the field of filteraids.

For more complete information on the application of Dicalite Filteraids to your processing problem, write

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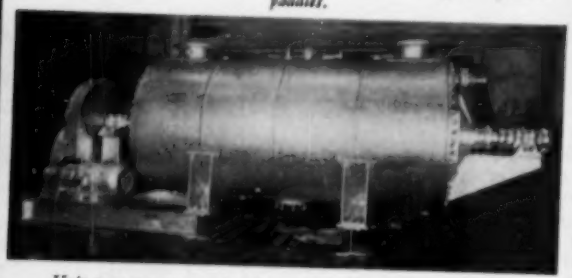
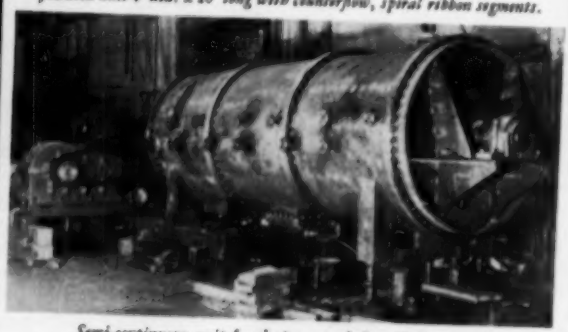
Batch blending and heat transfer provided by this unit. Stainless steel, stud-bolted steel jacket, 4' dia. x 10' long with pitched paddles.



Unit to evaporate organic solvents from sludge. Fabricated steel jacketed unit 4' dia. x 20' long with counterflow, spiral ribbon segments.



Semi-continuous unit for drying ore sludge. 5' dia. x 26' long scraper surface dryer undergoing mechanical and hydrostatic tests in our plant.

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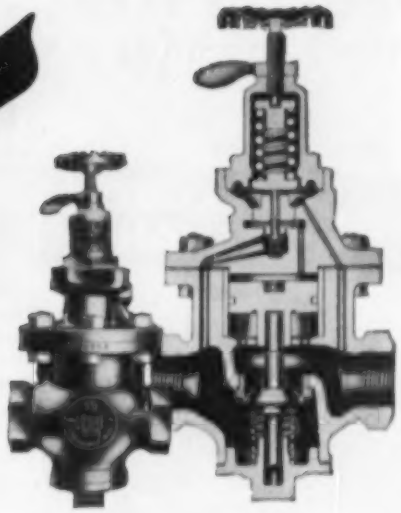

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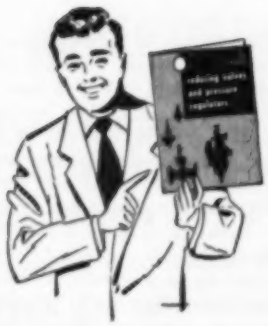

BULLETIN 5302

Provides latest engineering data on all classes of Leslie Pressure Reducing Valves—assists you in planning and specifying for optimum performance. Yours on request.

TYPICAL PRESSURE RANGES

CLASS	BODY MATERIAL	SIZES	INLET STEAM PRESSURES	REDUCED PRESSURE RANGE
LLK	Cast Iron	½"-6"	25-250	2-35
LK	Cast Iron	½"-6"	25-250	10-235
LL-3	Cast Bronze	½"-4"	25-300	2-35
L-3	Cast Bronze	½"-4"	25-300	10-285
LL-4	Cast Bronze	5"-6"	40-300	5-35
L-4	Cast Bronze	5"-6"	40-300	20-275
HS-2	Cast Carbon Steel & Cast Alloy Steels	½"-3"	300-750	100-600
HS-3		1"-3"	300-1500	100-600

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vapor conservation vents
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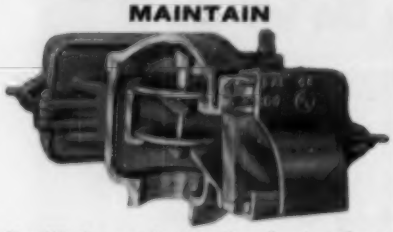
SIMPLE and EASY to MAINTAIN



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Vertical position of arrester permits condensate to drain off freely—prevents frequent "clog-ups" and prolongs operating time.

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Interchangeable arresters permit a spare to be inserted quickly and easily to safeguard tank while servicing original arrester.

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Precision fabricated valves are processed to assure tight seatings, and are available as specified on order for other than normal pressure settings. Stream-lined design assures maximum air-flow capacities and self-drainage of condensate.

SEE CHEMICAL ENGINEERING CATALOG, PAGE 1503

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about our authors . . .

SOMEWHERE, MEXICO—When deadlines are crowding and galley proofs aren't read by authors, phones start to buzz. At stake was January C.E.P., with author Clyde Berg not heard from. A check with his secretary at Union Oil in L.A. revealed he was enjoying a Mexican vacation, was likely at the moment to be in Acapulco. An hour later the radio told of the earthquake that had done severe damage to that beautiful community.

As it turned out, we couldn't know for sure for at least 24 hours that Clyde was all right, inasmuch as (1) the wires were down between Acapulco and the outside world, and (2) Clyde was about 350 miles south of Mexico City, where communication was allowed to begin to deteriorate some few centuries ago.

Clyde is shown exploring the ancient ruins of Zapotec Indian races known as "Mitla"—near Oaxaca.

MIDLAND, MICHIGAN—This is not a story about another absentee author. Instead, we proudly reveal a small part we had in helping put into final form a dynamic report on a community. What makes this community of Midland, Michigan, different? Two factors: the civic climate laid down by farsighted leaders, and the effect of chemical engineers and other technologists in civic affairs. You'll be able to read this stimulating report by W. R. Collings, president of Dow Corning, aided with illustrations by our Bill Anderson (profile), in the May C.E.P.

MADRID, SPAIN—We recently called Columbia U. to find out how Prof. Charles Bonilla's third Liquid Metals Symposium (New Orleans Meeting) was coming along. Were told "he's away on a short trip." "Where?" "Spain."

Now recently returned wearing a hand-tailored suit costing less than $50 U.S., Carlos (his Spanish pseudonym) tells he was for five weeks lecturing at Junta de Energia Nuclear, with co-sponsorship by our State Dept. and the A.E.C.

Professor Bonilla (left) with a group of students constructing an electrical analog board.

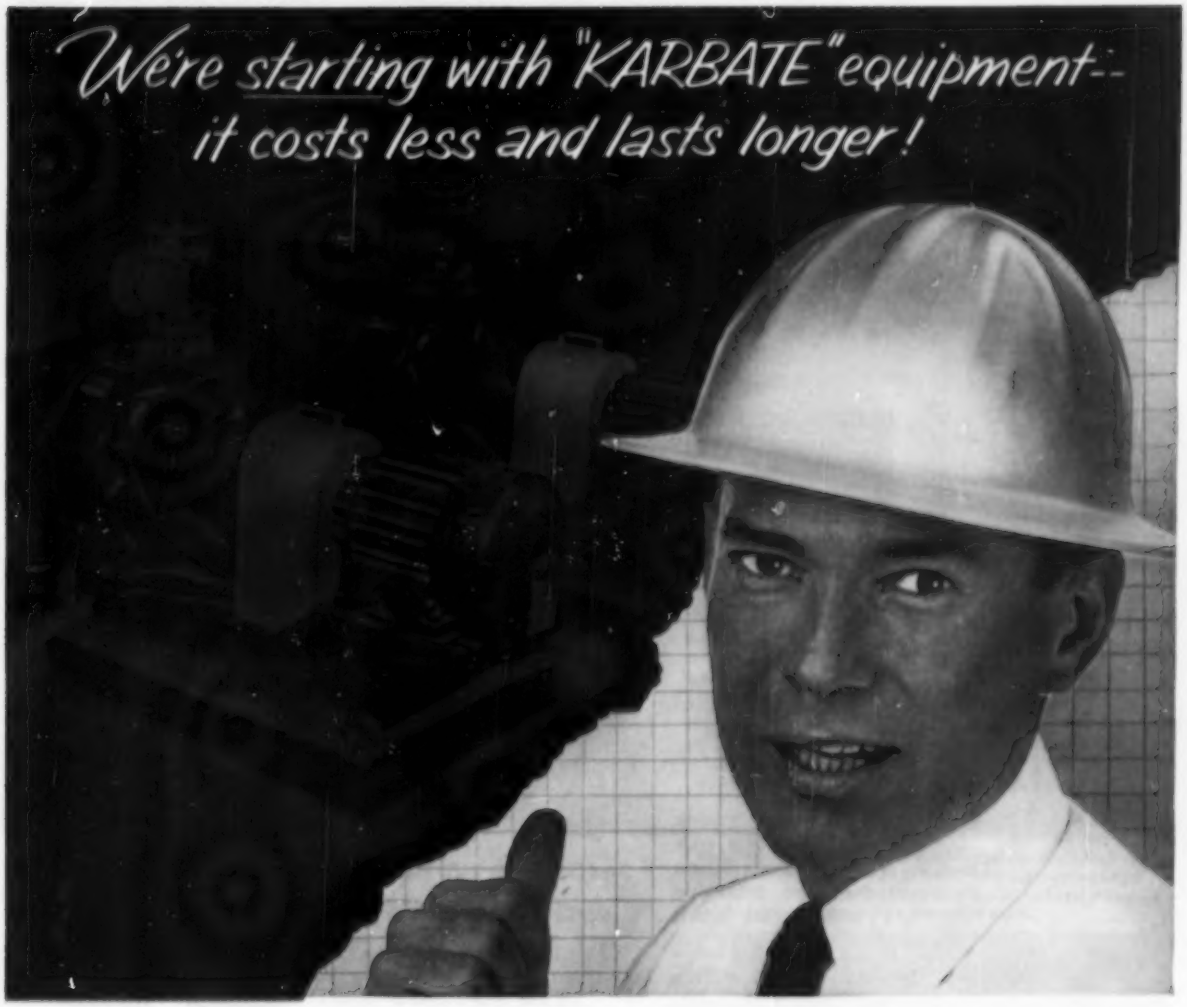
Employing facsimile paper and testing electric bulbs for use in analogs for heat transfer & fluid flow.

Purpose was to instruct some 22 engineering profs and advanced grad students in coolant flow and heat transfer design aspects of nuclear reactors.

Spain, he said, has one of Europe's more active nuclear power programs, having operated some six years, with 200 presently working full time. On order from the U.S. is a 200 megawatt research reactor.

Only major problem was how to take proper advantage of the "good buys" in two days shopping. Would have been no problem, says Carlos, if Mrs. B. had been along.

One purchase he didn't need Mrs. B.'s advice on, however, was a collection of hand-painted neckties he commissioned from a Spanish haberdasher and brought back as souvenirs for friends and associates. The hand-painted subject? An atomic reactor!



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See Process Filters in the Bowserama in your city . . . . . watch for announcement of dates.

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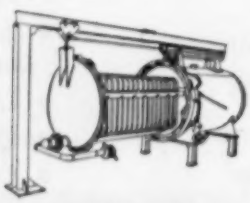
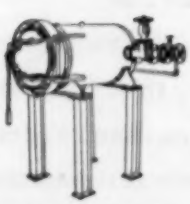


HORIZONTAL LEAF FILTERS



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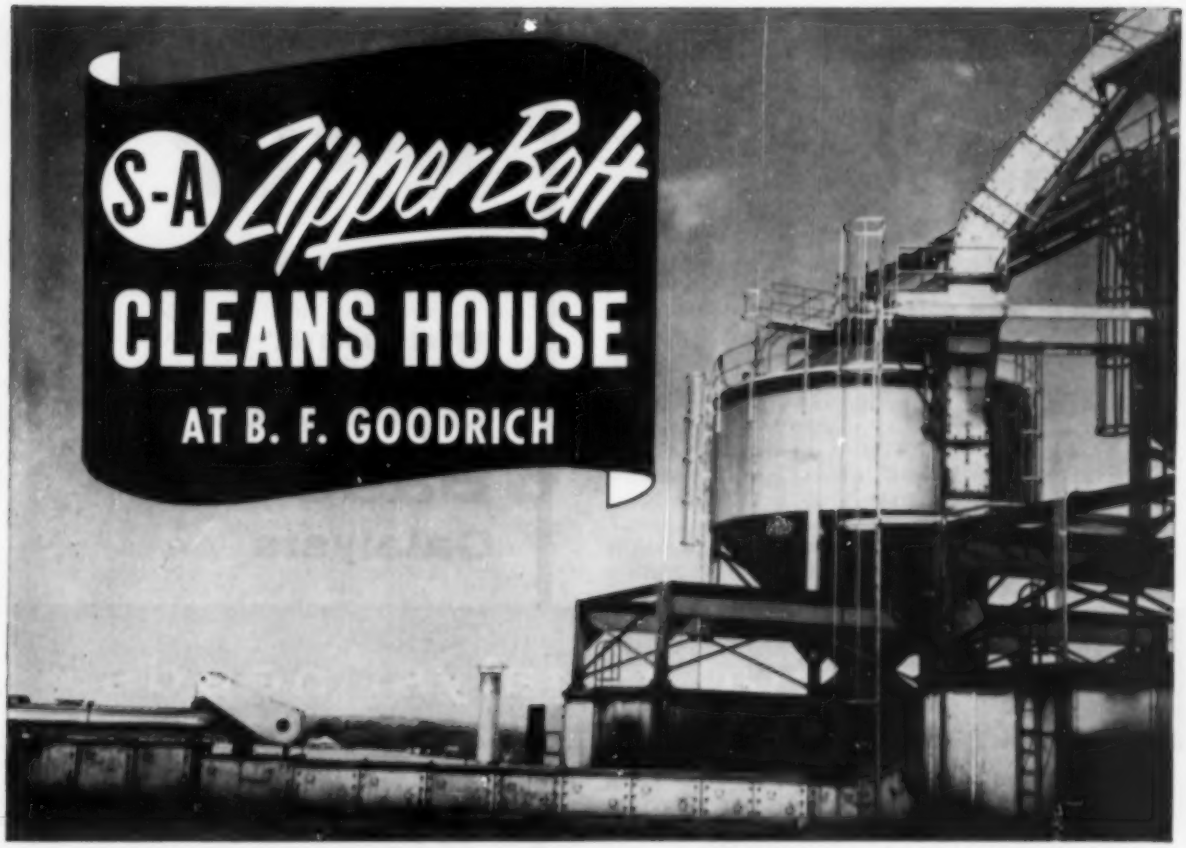

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To preserve the important but fragile structure of carbon black beads and at the same time eliminate dirt accumulation, B. F. Goodrich selected STEPHENS-ADAMSON "zip-in" conveyors for their Tuscaloosa, Alabama plant.

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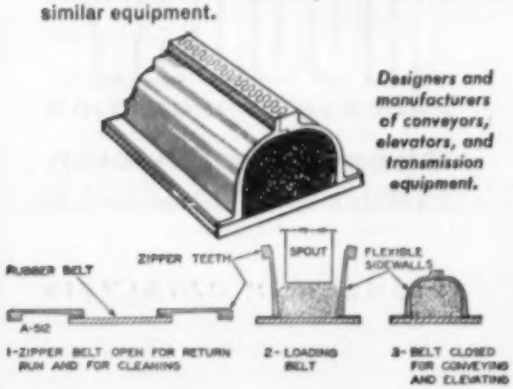
This installation is a direct result of the success which has been attained in Goodrich plants all over the country with similar equipment.

Enclosed in housing, this zipper conveyor runs 40 ft. horizontally and then 80 ft. on a vertical and inclined plane. Discharge is to either another horizontal zipper (see below) or to storage shown at right.

From elevator and storage section at left zipper conveyor runs 156 ft. horizontally, rises on an incline and discharges to additional storage facilities. Conveyor capacity—9½ tons per hour.



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PIONEER IN CATALYSIS

CEP trends / CHEMICAL BUSINESS

Last autumn C.E.P.'s Trends pointed out that the chemical industry, after about five years in which profits were more or less static, was apparently entering a new period of progress. If the business history of the industry repeats itself, this should mean that leading companies will climb onto a new plateau of earnings over the next few years.

Current events appear to justify this theory. The new trend became manifest in the first half earnings of 1955 and the published annual reports for the full year for the leading firms showed, almost without exception, new records in sales and notable gains in profits.

Quarterly Records

Figures for the first three months of this year are not at hand at this writing but checks with management and reliable estimates in investment circles indicate that the first quarter of 1956 will be well above 1955 and will, in many cases, again set new high records for a quarter. So far there are no disturbing signs that might point to a letdown in the chemical business in the near future.

Union Carbide, for example, is expected to show a net for the March quarter of $1.25 a share or more, up 25% from the March 1955 period.

Financial watchdogs think that both American Cyanamid and Allied Chemical will show the best first quarter earnings in their history this year—a good start on showing new records for the year.

A compilation of the record of last year's operations shows that 23 chemical firms reported total net of $858,178,000 earnings for the year, an increase of about 30% over net earnings of $660,000,000 in 1954.

While this percentage gain in earnings is not as large as the percentage gains shown by such industries as metals and textiles, which are subject to wider fluctuations in their business, the gain shown by the chemical industry is impressive on top of an already high and stable level of activity.

Standouts

A few firms showed more striking advances than the industry as a whole: Union Carbide reported net equal to $4.83 a share against $3.10 a share in 1954, a gain of 57%. This was partly due to the resurgence of the firm's formerly depressed business in ferro alloys which depend on the steel industry.

Dow Chemical for the six months ended November 30, 1955 had earnings equal to $1.22 a share compared with 71 cents a share earned in its 1954 six months period, a gain of nearly 70%. Another outstanding performer was Rohm & Haas, which showed the fancy figure of $17.23 a share for 1955 compared with $12.54 in 1954 and $6.73 in 1953. Rohm & Haas is one of the few sizeable chemical firms that has not split its shares, which accounts for the unusually high showing.

Figures for some of the other leaders in the industry are less notable but nevertheless must have made pleasant reading for their shareholders. Allied Chemical showed for 1955 net equal to $5.72 a share against $4.80 in 1954. American Cyanamid reported $4.07 a share against $2.95 a share and Hercules Powder $6.90 a share against $5.30 a share. Hercules is now in process of splitting its shares three for one. Du Pont came up with record net for last year equal to $9.26 a share against $7.33 in 1954. Of this $6.51 a share in 1955 came from its operating earnings as a chemical firm, against $5.30 a share in 1954. The balance came from dividends from its somewhat fantastic holdings of over 20 million shares of General Motors currently valued in the stock market at around $1,000,000,000.

The Drug Picture

Drug firms, though also considered "growth stocks" in Wall Street parlance, had only a modest gain in earnings of 16% last year over their results in 1954. A list of 12 companies had net earnings of about $107 million against $92 million in 1954.

This is partly because the drug industry has lately been less dynamic in its growth than the chemical industry and is also more competitive. Only a few smaller firms that have made some major developments on their own, such as Norwich Pharmacal and Schering, made gains comparable to those shown by chemical companies.

There are a few indications, however, that a number of the leading drug firms may have a considerably better year in 1956 than they had in 1955.

Heavy sales of Salk vaccine expected this year should augment profits of such firms as Eli Lilly and Parke Davis. Last year, because of sales to Foundations at cost and because of the ruckus over the purity of the vaccine, it is probable that profits were scanty. Some of the newer mental drugs now climbing into big time sales volume will help firms like Smith, Kline & French and the Wyeth Division of American Home Products.

Confidence of the chemical industry in its future is shown by its continued heavy expenditures for plant expansion. The Manufacturing Chemists Association estimates that $1,600,000,000 will be spent on plants in 1956 and 1957 of which now $1,100,000,000 is in plants actually being built with the balance under commitment.

First "service" station for submarine reactors ...transition shield of LEAD brick

Here's something new in the swiftly advancing technology of atomic power . . . a chamber devised for recharging reactors of submarines . . . and maybe, someday, reactors of ships, planes, locomotives and stationary power plants. Here, shielded by lead, men can service equipment safely.

The specially designed bricks were produced by National Lead. They stack and fit perfectly, in a circle . . . without mortar. Inner surfaces are contoured to the chamber arc. Interfaces are also curved . . . to mate and mesh in a structurally sound configuration. Nowhere does a crack offer a straight-line path for radiation.

Maybe you need lead brick . . . extruded, curved "Protecto" brick . . . or conventional, flat-sided extruded brick. Maybe you want lead in some other standard form . . . sheet, slab or sleeving, for instance. Maybe you want some specially built shape.

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CEP

opinion and comment

The appointment of Walter G. Whitman, Clifford C. Furnas, and now Eger V. Murphree to technico-administrative posts of extremely high level in government suggests a recognition trend that is interesting to consider.

These three appointees are eminent chemical engineers who have had extensive experience in other governmental work involving sizable projects, too numerous to cite here. For the profession, Whitman is currently president and served in other posts of the Institute as all readers know. Furnas was a director in 1945-47. Murphree just completed a directorship that began in 1953.

Murphree's recent appointment to the role of "guided missiles czar" makes him a special assistant to Defense Secretary Wilson. Furnas is on sabbatical leave from the University of Buffalo where he was chancellor, and is Wilson's staff assistant Defense Secretary for research. Whitman was made Secretary General of the Conference on Peaceful Uses of the Atom at Geneva last year.

The gravity of the world race to achieve intercontinental guided missiles is such that in effect the role accorded to Murphree may well be one of destiny, not just for the man Murphree, but for all of us.

It is interesting to conjecture whether in selecting Murphree, Whitman, and Furnas for these roles, the fact that they are chemical engineers had particular bearing. It can be of course that as unusually able people, they were selected primarily for other qualities. In these days of our growing dependence for security, even survival, on increasingly complex technology on a massive scale, it seems likely, however, to find an extremely able leader who is also a broadly trained technologist, will undoubtedly prove to be a decided asset.

As Whitman's role in the U. N. focussed the attention of people everywhere on the strong relationship between the chemical engineer and atomic energy, it can be postulated that a similar effect is again taking place. The presence of a prominent chemical engineer in the top role of the guided missiles program is doubtless getting across to many, that there must be an important connection between chemical engineering and guided missiles. Fortuitously, this issue of C.E.P. carries an article on just this subject entitled "Chemical Engineering Aspects of Jet Propulsion," by Rapp, which many readers may find surprisingly informative.

Members of the profession may well feel a strong sense of pride concerning the status and responsibility accorded their associates, and also one of gratitude that these grim matters are in such good hands.

J.B.M.

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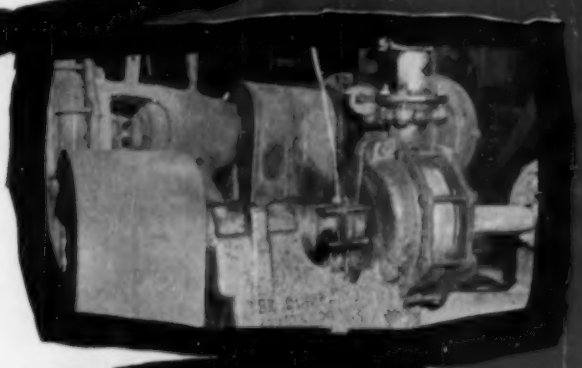

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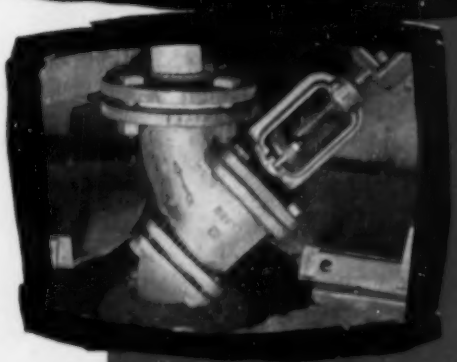

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THE BEGINNING OF A NEW ERA

J. C. Lawrence | Chairman, A.I.Ch.E. Standards Committee

STANDARDS in our industries are not new. For years we have benefited from A.S.M.E. safety codes for unfired pressure vessels and boilers. Then, too, we have many valuable mechanical standards including the A.S.A. code for pressure piping, the M.S.S. (Mfrs. Standardization Society) standards for valves and fittings, and hundreds of others which assure even such taken-for-granted functions as light bulbs fitting sockets, nuts fitting bolts, and so on. One of the most valued programs of standardization has been carried on by the A.S.T.M. with regard to materials testing.

It is only recently, however, that we have come to appreciate that we may achieve the benefits of dimensional standardization of certain items of processing equipment. In the past, we have felt assured that the advantages to be had from custom design greatly outweighed the advantages arising from the use of designs arbitrarily comprised to achieve standardization.

Before us seems a new era—one in which we can have both interchangeability and custom engineering. In the case of centrifugal pumps, this means that, for a given rating, we may find it possible to have various designs and manufacturers' interpretations able to fit interchangeably into a given space.

The same can be expected for heat exchangers, distillation towers, and a host of other items closely concerned with the functioning of the chemical engineering process.

What are the advantages to be expected from such dimensional standardization? What will the disadvantages be? In the two excellent articles which follow (Brand and Murdock), these are discussed in a manner which should make many of the issues clearly understood.

How will such standardization be achieved? The present effort is centered primarily around centrifugal pumps. The main agency for working out pump dimensional standardization is Sectional Committee B-73 of the American Standards Association. This committee is made up of about 30 representatives of process operating, pump manufacturing, and other firms and organizations including the A.I.Ch.E. The committee has two official sponsors, the Manufacturing Chemists Association and the Hydraulic Institute, with the former handling the clerical and other administrative responsibilities. Historically, B-73 was an outgrowth of a recommendation made to the A.S.A. by the Chemical Industries Advisory Board, a subdivision of A.S.A., following its survey of views of the chemical industry and the pump suppliers.

Today, the M.C.A. has a Committee on Mechanical Equipment Standardization, the primary purpose of which is to conduct preliminary studies to determine the fields with the most potential for savings from standardization activities, and to initiate projects through the proper channels for bringing these savings to fruition.

The A.I.Ch.E. has two committees working on different aspects of standardization. One of these is the Equipment Test Procedures Committee, the purpose of which is the development of standard testing procedures—a vital aspect of standardization between buyers and sellers at both purchasing and acceptance stages.

The A.I.Ch.E. Standards Committee was authorized by Council at its December 1954 meeting to "develop standards and codes of importance to the chemical industry and to the chemical engineering profession. It shall confine its activities to the screening, investigation, and development of standards and codes that are clearly considered to be chemical engineering and chemical industry standards."

Inasmuch as the A.S.A.'s B-73 is proceeding with centrifugal pumps, the A.I.Ch.E. Standards Committee is cooperating to the fullest extent including the providing of representation.

Two subcommittees of the A.I.Ch.E. Standards Committee have recently been formed, representing fields in which we shall be working to develop standards. These are for heat exchangers, and for carbon steel bubble cap distillation columns ranging from 15 to 400 lb./sq. in. ga. operating pressures.

Recently, the A.I.Ch.E. announced its support of the formation of a proposed A.S.A. Nuclear Standards Board. To date, the Institute has offered to be a sponsor of a Sectional Committee on Chemical Engineering in the Nuclear Field, and another on Reactor Hazards.

There are others working on standards of value to the chemical process industries. The intention of this brief introduction is to highlight certain activities and slight no one. In general, it can be said that with the momentum now under way, it seems that we may really begin to see process equipment standardization become a practical reality. From the estimates of the M.C.A. that chemical industry growth may make it 500% as large by 1975 as it was in 1950, it is not difficult to picture the dollar benefit involved as important to our economy.

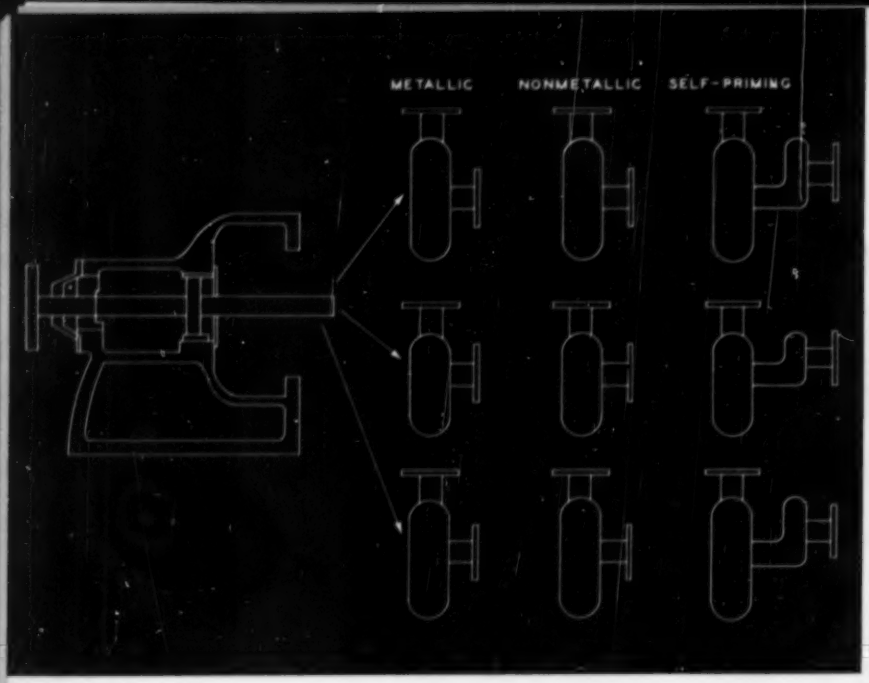

Fig. 1.

Dimensional Standardization of Centrifugal Chemical Pumps

WHAT THE CHEMICAL INDUSTRY WANTS

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In industry as in business, a proper balance of all the factors influencing its profits is necessary if profitable operation is to be assured.

These influencing factors can be broken down into two main categories: the *external influences* of demand, quality, and selling price originating in competition, and the *costs* involved in converting raw material to finished product. The purpose of this article is to discuss ways by which the profitability pattern can be improved through certain adjustments of internal costs, those involved in converting raw material to finished product. Factors influencing these conversion costs, particularly those pertaining to the equipment in which the raw materials are converted, are summarized as:

1. performance
2. mechanical reliability leading to infrequent maintenance and replacement
3. downtime leading to production loss
4. safety
5. equipment cost
6. engineering time
7. installation costs
8. inventories
9. replacement costs when required
10. repair cost when required

National Standardization

As the subject of this article is centrifugal pumps, emphasis will be centered on a national standardization program for centrifugal pumps used in the chemical industry. An attempt will be made to bring out the savings involved and the feasibility of such a program.

Why hasn't this been done before?

Since the factors influencing the conversion costs listed above have always existed, it may well be asked why in the field of centrifugal pumps they are only now being given such major consideration.

It has been said that it was around the early 1900's that the chemical industry really "took off." That period initiated its recognition as a major industry and the centrifugal pump began displacing older types of pumping equipment. Because the chemical industry was comparatively insignificant and because it was concentrating on developing new products, new processes, and in short, on manufacturing chemicals with all its cost consciousness focused on raw materials and low capital investment giving little consideration to the

maintenance of its mechanical equipment, the centrifugal pump was developed for the utilities primarily to pump water.

At this time equipment to the chemical industry was merely a means to an end. Plants were run usually by chemists with operators and repairmen keeping the equipment in operation and on occasion even the chemist pitched in. Baling wire was the key item in the storeroom. Engineering attention to equipment maintenance is a comparatively recent development. Therefore, the chemical industry with all its special pumping requirements, such as slurries, pastes, and viscous, volatile, toxic, and corrosive liquids struggled along using water pumps wherever possible. Where these could not possibly be used, the chemical industry paid for modification, special designs, and special materials of construction. Of course, all during this time each pump was an individual design with little attention given to interchangeability or inventory reduction.

The chemical industry continued to grow until in the latter part of the 1930's to the middle 1940's several factors caused a major change in its thinking. The European war required its production to maintain capacity rates, and new construction was severely limited. This placed shutdown time at a premium. Continuous processes were being evolved in which reliable operation was even more critical. Meantime labor practices changed drastically and labor wage rates increased rapidly. As a result, the value of repair time took on new importance. In order to protect production, parts inventories soared to new heights. Interchangeability and dependability became prime considerations; in short, both the criteria for quality and the maintenance practices were brought forcefully into the limelight and found wanting.

Here we are

Plants growing up in the tradition just outlined find themselves with a multitude of pumps of various types, styles, and designs, each pump having been purchased for a specific application. In one such plant there are 1200 pumps installed and more than 400 different types and styles that are not interchangeable. An analysis shows that the capacities in many of these pumps do not vary more than 5 gal./min., or the head more than several feet, and shaft diameters vary for no apparent reason. A recent study by one company based on nine manufacturers' pumps in the capacity range of 5-500 gal./min. revealed sixteen shaft diameters—some sized by the 1 or ½ in., some ⅜, and some 1/16 in. One shaft was even in decimals. No wonder couplings and mechanical seals are so expensive! One manufacturer of seals estimated that if standards could be established on shaft diameters where the shaft goes through the stuffing box, prices of seals could be reduced by approximately 50%.

It is obvious, therefore, that in order to protect this multitude of types and styles of pumps and their related components, inventories of spare parts become completely unreasonable. Management then exerts pressure to decrease them, consequently, the dilemma of either high inventories, or high replacements costs, and of more shutdown time. In newer plants attempts have been made to standardize on one or two manufacturers' pumps in order to solve this problem and effect lower inventories, decreased shutdown time during replacement, and decreased replacement costs. This too has been found disadvantageous, for such plants are unable to capitalize on new improved designs as they come on the market because of the tremendous cost involved in changing over; also, they are completely at the mercy of one supplier for deliveries and service in general, perhaps even price, especially regarding spare parts. At the present time whenever one manufacturer's pump is replaced with another's pump, concrete foundations must be knocked out and replaced, piping changed, and electrical conduit relocated, all of which leads to tremendous costs both because of the labor involved and the production lost.

In engineering, a separate foundation design for each manufacturer's pumps is required. Certified prints with dimensions must be obtained before piping and foundation drawings can be made. This not only delays engineering but also requires extra expense in merely obtaining the dimension sheets. Pumps must be analyzed in detail because there is no minimum standard for quality as has been pointed out (*1*). All these things lead to high costs in engineering as well as in construction.

A subcommittee of the chemical industry's advisory board of the American Standards Association estimated that the replacement and maintenance costs for centrifugal pumps in the chemical industry average approximately 50% of the initial investment annually because of the following:

1. **lack of interchangeability**
2. **difficulty of maintenance**
3. **high inventory**
4. **engineering problems associated with the varying of basic dimensions and features**

The solution

This same committee has agreed that there is only one answer, namely a national standardization program on centrifugal pumps to establish a definition of quality for the chemical industry, and a design pattern involving desirable features within a standard dimensional framework which will allow interchangeability between the various manufacturers' comparably rated pumps.

This committee concluded that:

1. **a definite need exists for a standardization program on centrifugal pumps;**
2. **pump standards are feasible;**
3. **estimated savings to the chemical industry alone will be $6,800,000 annually—a real opportunity and challenge.**
4. **a project should be initiated under the A.S.A. to develop such standards.**

The members of the committee thought that through such a program, lower replacement costs due to dimensional interchangeability would be effected, that there would be a reduction in capital investment on new construction, a reduction in design time, construction labor, storeroom space required, and that the maintenance costs would be decreased considerably due to certain desirable features being made standard.

Can it be done?

Since the quality side of this problem has been discussed (*1*), the rest of this discussion will concentrate on the feasibility of standardizing external dimensions.

Approximately eighteen months ago an investigation was made of pumps by one major chemical company for the purpose of developing a standardization program. It quickly became obvious that there is a trend among the pump manufacturers to design a standard bearing bracket which will accommodate various-sized volutes in the different alloys (Figure 1).

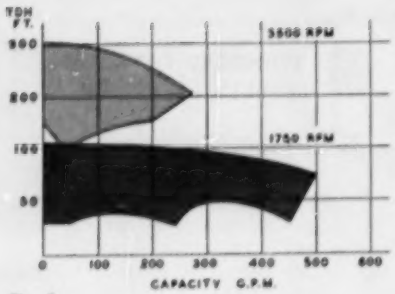


Fig. 2.

Table 1.

Capacity 100 gal./min. × 70-ft. head

1750 rev./min. open impeller

mfr.	size pump	size imp.	motor
A	2 × 1½	8¾	5 hp.
B	2 × 1½	9	5 hp.
C	2 × 1½	8¾	5 hp.
D	2 × 1½	8½	5 hp.
E	2 × 1½	8½	5 hp.

Table 2

mfr.	max. size casing for particular bearing bracket in.	in.
A 1	4	× 3
A 2	4	× 3
B 1	4	× 3
C 1	4	× 3
D 1	2	× 1½
D 1	4	× 3
C 2	4	× 3
D 2	2	× 1½
D 2	6	× 5
E 1	3	× 1½
E 1	4	× 3
E 1	1½	× 1½

It was stated previously that the costs involved in converting raw materials to the finished product needed adjustment to accommodate the pressures of the external influences of demand, quality, and selling price. It is apparent that this is the pump manufacturer's attempt to obtain higher productivity within his industry and therefore, to meet these demands. Each manufacturer has tried to cut costs by standardizing as much as possible within his own line of products. This, of course, helps meet some of the internal requirements of the chemical industry. However, it still does not define the quality level of centrifugal pumps required for the chemical industry nor does it provide dimensional standardization so that comparably rated pumps of different manufacturers will be interchangeable.

When the trend among manufacturers to design one bearing bracket to accommodate various-sized volutes was recognized, it seemed possible that the external dimensions of these pumps might be standardized to effect the interchangeability required. There were many comments to the effect that such an approach was impossible because each manufacturer had designed his pump to different capacity and head requirements, and that the various manufacturers had met these capacity and head requirements differently. Therefore, in order to determine the feasibility of dimensional standardization the following three steps were necessary:

1. determine whether the same size pump was offered for a given head and capacity.
2. determine the range of pump sizes that one bearing bracket would accommodate and the variations in these ranges. (It was assumed that this step would also establish whether or not the manufacturers had designed to the same range of capacities and heads).
3. determine, based on the above answers, the dimensional differences for:
   a. the bearing bracket alone
   b. the total external dimensions for comparably rated pumps.

Five representative manufacturers who were known to have made an effort to design pumps specifically for the chemical industry were considered in this study and will be designated as A, B, C, D, and E for the purposes of figures and tables.

STEP 1.

Under step 1, that of determining whether the same size pump was offered for a given head and capacity, it was quickly established that in broad areas the pump size offered for a predetermined capacity and head was for all practical purposes the same.

It is obvious that each manufacturer met the specification (see head of Table 1) by using the same size pump, and approximately the same diameter impeller, and the required size motor. This does not, of course, mean that each manufacturer used precisely the same amount of horsepower, but it certainly indicates that the horsepower required is within range.

STEP 2.

The second step, that of determining the range of pumps mountable on one bearing bracket and the variations in these ranges, was not quite so easy as step 1.

It was noted first that all the manufacturers' views coincided in changing the size of the bearing bracket at 4 × 3 in. volute size with the rating of approximately 450-500 gal./min. and about 75- to 100-ft. head. These required 15-hp. motors and 1750 rev./min. with open impellers. A few offered a little higher rating for the same size by increasing the impeller diameter and horsepower required. However, the range given here is a good average and covers the majority of the chemical industry requirements.

It can be seen in Table 2 that there is a common break at the 4- × 3-in. volute size. Other than this, the size seems to vary as can be seen by manufacturer D and E. It is interesting to note that D2 did not coincide with the pattern, but had a break at 6- × 5-in. volute. This pump was not designed for the chemical industry but rather for general use, whereas D1 was designed for the chemical industry.

Figure 2 shows the general range covered by the pumps up to and including the 4- × 3-in. size.

It can be seen from Figure 2 that the manufacturers designed (as said before) to approximately 500 gal./min. at around 75- to 100-ft. head using 1750 rev./min. and open impellers. This figure also shows that the use of 3600 rev./min. pumps has effected a pump design to reach approximately 250- to 300-ft. head. By this figure, it is not meant to convey that each manufacturer cover this over-all range exactly the same, but that they all design pumps to cover this range with the largest pump being size 4 × 3 in. It should be pointed out also that some manufacturers overlap the 1750 and 3600 rev./min. ranges shown here. For example, one manufacturer may attain a 175- or 200-ft head at 1750 rev./min. by using a 12- or 14-in. impeller, whereas another manufacturer may cover the range of heads from 70 to 100 ft. with 3600 rev./min. using small casings and impellers. However, the range shown here is usually the common denominator covered by casings up to and including the 4- × 3-in. size. Those casings covering the overlapped areas are usually additions to the line mountable on the same bearing bracket and offered to meet their particular customers' desires or requirements.

Of the five manufacturers considered, three offered volutes to cover this complete range on one bearing bracket; one manufacturer required four bearing brackets including both cast iron pumps and alloy pumps; and one manufacturer required seven bearing brackets. Of the manufacturers offering this range on one bearing bracket, it is not necessarily to be understood that they do not have other bearing brackets available. Rather is it stated here that the range shown on Table 2 can be covered

by them with various-sized volutes on one bearing bracket. This is definitely the trend as the manufacturer requiring four bearing brackets is presently redesigning, and the one requiring seven bearing brackets has already brought a completely new pump on the market.

The manufacturer using seven bearing brackets to cover this range is a good example of the old approach, designing a bearing bracket, shaft, etc. for each pump. This, of course, is hard on interchangeability and inventory and cannot be mass produced in the quantities accessible to the newly designed pump.

STEP 3.

This leads up to the third step of the study—determining the dimensional difference for (a) the bearing bracket alone, and (b) the total external dimensions for comparably rated pumps. It has been seen from the preceding steps that given a particular specification the manufacturers meet it pretty nearly the same. It has also been seen that they have all designed to the same basic capacity and head range with one or more bearing brackets. Figure 3 shows the dimensional differences of these bearing brackets.

Where manufacturer D required more than one bearing bracket to cover this range, the dimensions shown are for the one which best fit the dimensional pattern of the other manufacturers shown.

Manufacturer E was eliminated completely because the dimensions of his bearing bracket did not seem to fit the pattern and, since he was redesigning it, it did not seem important.

Manufacturer A offers two bearing brackets both of which will accommodate volutes covering the entire range shown on Figure 2. One is oil lubricated and one is grease lubricated. The one shown is the grease lubricated, which again was chosen because it seemed to fit the general dimensional pattern.

Manufacturer B offers a smaller bearing bracket for its smaller pumps only. However, the one shown here will accommodate volutes covering the entire range shown on Figure 2.

Manufacturer C offers casings that will accommodate extremely large impellers in order to attain high heads at 1750 rev./min. The 4- × 3-in. pump mounting on this bearing bracket will produce a capacity of approximately 600 gal./min. with about 20 hp.

It can be seen from Figure 3 that the dimensions are surprisingly similar in many instances. Dimension A requires only minor adjustments with the exception of Manufacturer A's dimensions, of course. Dimension B is quite similar with the exception of Manufacturer C, who could possibly add some "ears" to increase this dimension. Dimension C is quite similar with the exception of Manufacturer A. It is interesting to note that if this manufacturer could move his front bolts approximately 2 in. they would also fall in line with Dimension A as well as this one. Dimension D varies only slightly and might be adjusted with shims.

The dimensional differences including a volute are shown in Figure 4. The group of bearing brackets are the same ones shown on the preceding figure. The 2- × 1½-in. volute size was arrived at by specification and not by arbitrarily selecting like sizes of the various manufacturers. It is obvious that the dimensions here are more diversi-

Fig. 3.

mfr.	name	size max. in.	frame dimensions A	B	C	D	E	F	G	ø
A	2	4 × 3	9½	7	14¾	7	9	12	2	½
B	1	4 × 3	7¼	7	12 5/16	7	9	10¼	1¼	⅝
C	1	4 × 3	7¼	4	12⅝	6¼	5	9⅝	1⅝	9/16
D	1	2 × 1½	6¾	6½	12⅝	5	8	10 1/16	1 1/16	⅝

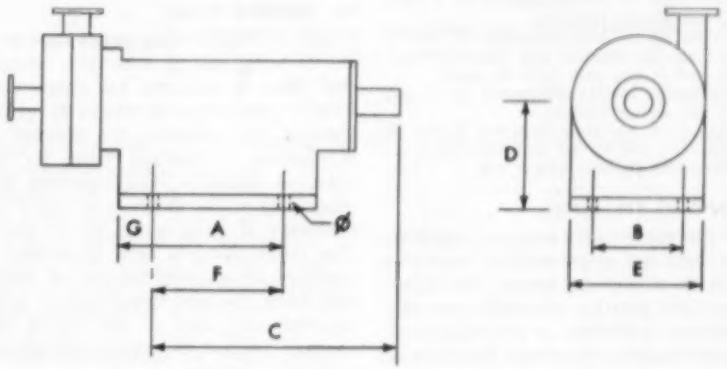
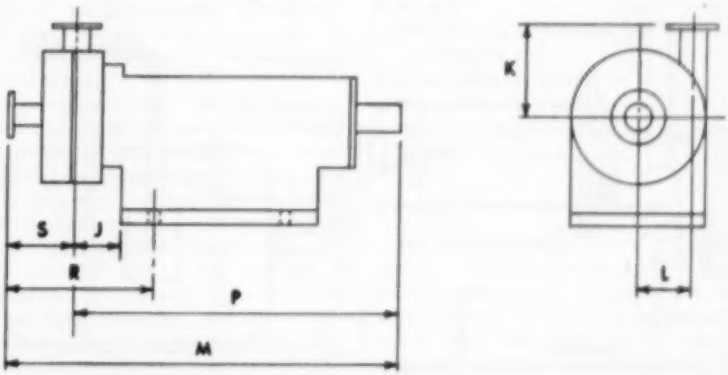


Fig. 4.

mfr.	name	size in.	external dimensions R	M	P	S	L	K	J	G
A	2	2 × 1½	9 1/16	23 15/16	19¾	4 5/16	5 1/16	7	4	1
B	1	2 × 1½	7¼	19 15/16	16 5/16	3⅜	6	7¼	2⅜	1¼
C	1	2 × 1½	5⅜	19⅜	16⅛	3½	5¼	9	2⅛	1¼
D	1	2 × 1½	7 1/16	20 3/16	16 1/16	4⅛	0	8¼	1 1/16	1 1/16



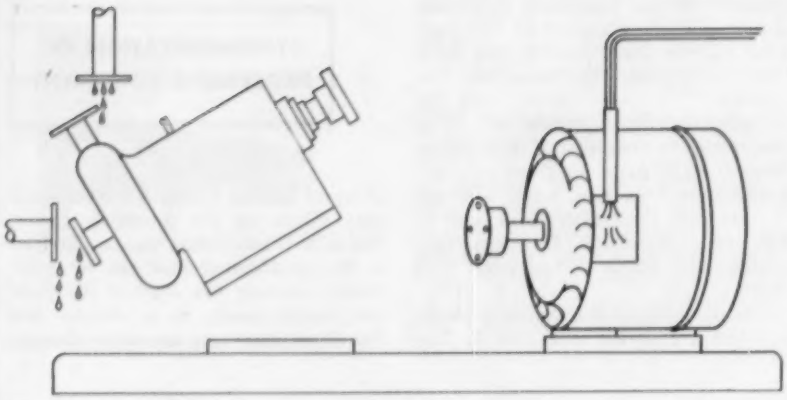


Fig. 5.

fied than those concerning the bearing bracket alone. However, there are some areas in which the dimensions are almost identical, for example:

1. dimension R—Manufacturers B and D only 1/16 in. apart.
2. dimension M—Manufacturers B, C, and D are less than 1 in. maximum apart.
3. dimension P—Manufacturers B, C, and D are almost identical.
4. dimension S—Manufacturers B and C are almost identical and Manufacturers D and A are only 1/16 in. apart.
5. dimension L—Manufacturers B, C, and A are within 5/16 in.
6. dimension K—Manufacturers B and A are only 1/4 in. off and manufacturers C and D are only 1/4 in. off.

Purpose of the Study

It has not been the purpose in making this study nor in presenting the results of it to attempt to resolve the differences; the purpose originally was only to determine whether or not dimensional standardization was within the realm of feasibility. From the results presented here, it seems quite plain that it is. However, there are many problems involved which are receiving thorough attention by a sectional committee established under the A.S.A. for the express purpose of developing standards for centrifugal pumps used in the chemical industry. This committee is composed of representatives from the chemical industry, the petroleum industry, the pump manufacturers, the packing and mechanical seal industry, and all interested parties. It feels sure that tremendous benefits will be realized by all industries involved through this united effort.

No "Standard Pump"

One additional thing seems appropriate to bring out at this time, namely that there is not, nor has there ever been in anyone's mind within the group studying this question the concept of establishing *a standard pump* for the chemical industry. The ingenuity and originality of the designer is absolutely necessary if progress is to be made. The move outlined here is seeking a standard dimensional framework which will allow the new developments to be received and used to the fullest advantage without the costly changeover presently required.

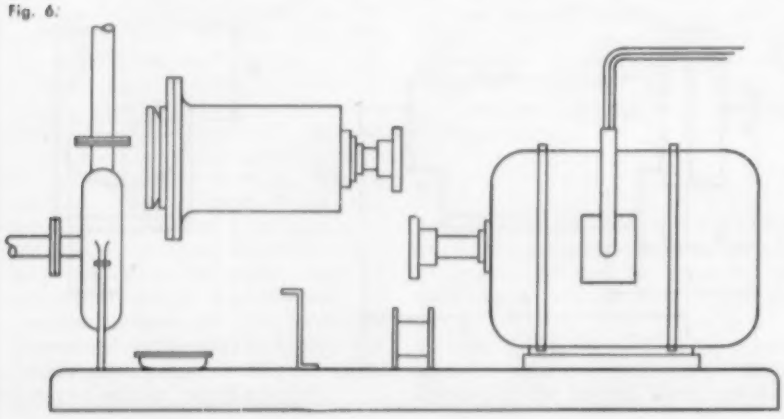
A New Development

Discussion thus far has dealt with pumps of the conventional design where the volute is supported by the bearing bracket. No doubt many are wondering about the new development which has recently come on the market where the casing is supported independently and remains in the line while the remainder of the pump is replaced.

Figures 5 and 6 illustrate the conventional and new designs, respectively.

As can be seen from these figures, the two pumps are considerably different in their design. This new development derives from the refinery-type centerline supporting pump redesigned for the chemical industry. It has the advantage of requiring only one craft for replacements unless, of course, the volute must be removed. Also, replacements are completed more quickly decreasing downtime. However, at the present time its first cost is a little higher. This is supposed to correct itself as production increases. It is not the purpose of this paper to evaluate the pros and cons of the new design, but merely to acknowledge that it exists. Resolving this one design should be a real challenge to the A.S.A. Committee. In fact, because of the radical differences between the two designs, it is possible that a dimensional standard may be established for each. However, they quite possibly can be accommodated on a standard base plate with the suction and discharge dimensions so standardized on the volutes that a change from one-type design to the other would not require the expense of altering the base or the piping as long as comparably rated pumps are used.

Fig. 6.



Things to Anticipate

Those men who served on the original exploratory committee are enthusiastic about this move towards standards as it appears to be the beginning of a new concept in the chemical industry. This industry has grown to a place where, based on its assets, it is the fourth largest industry in the nation and it has recently been forecast that it will triple in size by 1970.

There appears to be no reason why similar projects should not be initiated in the near future for items such as general-purpose tanks, heat exchangers, and agitator drives, to mention a few. With the chemical industry possessing this industrial stature coupled with its new awareness of this virgin territory for savings in the field of mechanical equipment, it seems that the chemical industry is standing on the brink of a new movement to standardize the mechanical components comprising its plants.

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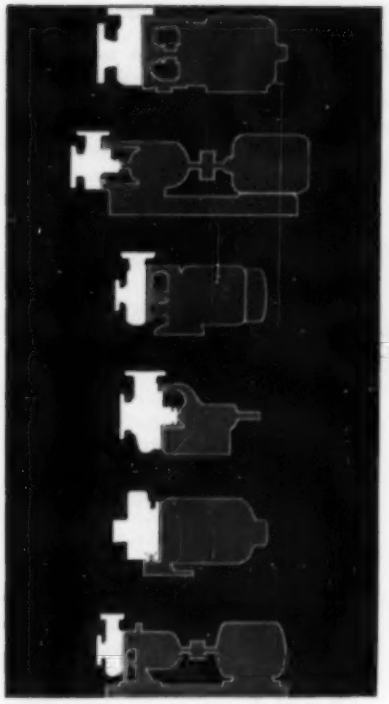

STANDARDS FOR HORIZONTAL END-SUCTION, SINGLE STAGE CENTRIFUGAL PUMPS

WHAT THE CENTRIFUGAL PUMP MANUFACTURERS CAN DO

Some ideas on the reactions of centrifugal pump manufacturers to the general theme of developing a set of standards for horizontal, end-suction, single-stage centrifugal pumps suitable for the chemical industry are enunciated in this paper. The opinions expressed here represent the consensus of a typical group and not of a single company.

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In the pump industry, as in any industry, increased standardization of parts, items, or units produced has been one of the underlying objectives of operations. This basic concept is a fundamental principle of the American economy. It has produced more goods for more people at a cost within the reach of the majority of the ultimate consumers.

Pump manufacturers, operating under and within the competitive economy, have of their own volition (and also through necessity) undertaken standardization of parts and units to the maximum degree. In order to obtain the benefits of volume production, their program is a compromise between economy of manufacture and consumer requirements.

Standardization has taken place in the categories of pump parts, mounting techniques, and interchangeability.

Parts: Efforts have been made to design parts that will be usable in as many different sizes and types of pumps as possible. These efforts apply primarily to glands, lantern rings, packing, and shaft sleeves. In cases of impellers, casings, and cover plates, manufacturers have sought to achieve interchangeability, if feasible, among many different models.

Mounting: The accompanying illustrations point up the fact that the liquid end of the pump does not know how it is mounted. In other words, the same casing and impeller can be mounted in a close-coupled mounting, in a frame-mounting, and can be adapted also to special mountings that may be required by any one particular customer. This is the basic idea behind the interchangeability of a liquid end of the pump between various types of mounting. Also several sizes of liquid ends can be mounted on a given size frame mounting. This keeps the number of frame sizes to a minimum.

If the question, naturally enough were asked, why the close-coupled type of arrangement is shown when the chemical industry is concerned only with the frame-mounted unit, the answer could be found in the records of the Hydraulic Institute (*1*), and necessary information obtained from a number of representative pump companies. These records show that a large percentage of the pumps are sold with the close-coupled mounting.

Interchangeability: The problem of interchangeability of casings and impellers between frame-mounted and close-coupled arrangements is a serious one for a majority of pump manufacturers. It must be taken into account in the general over-all development of standards. For in setting up any set of standards, the ultimate ones must be simple, understandable, and justifiable, economical to both the producer and the consumer. It should be stated here that standardization or interchangeability of the liquid ends between various types of mounting has taken place only within individual pump companies.

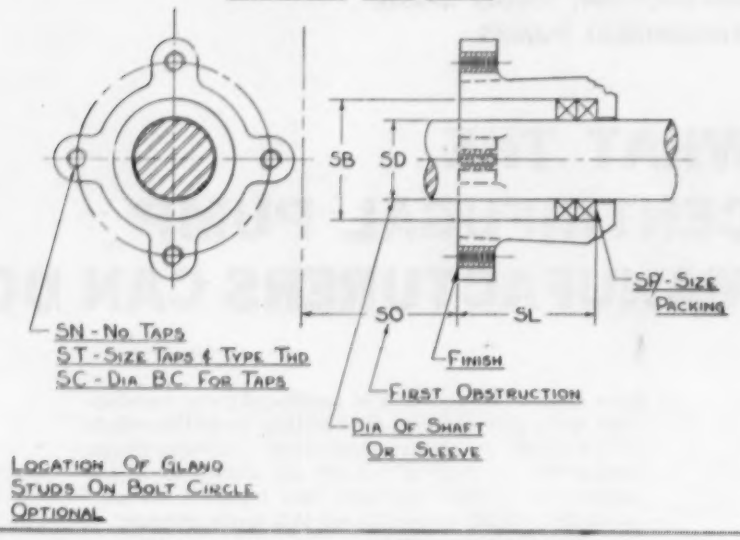
In addition to the work done by the individual pump companies in standardization and interchangeability, the Hydraulic Institute has, on an over-all basis, developed and published standards (*1*) which apply to such items as listed below. These standards definitely affect and clarify the items under consideration. Such standards prevent misunderstandings in terminology, definitions, procedures, etc., between the consumer and the supplier. Subjects covered include:

a. definitions and notation
b. application
c. rating
d. test code
e. instructions for installation, operation, and maintenance
f. friction tables for water
g. friction tables for viscous liquids
h. materials of construction for pumping various liquids

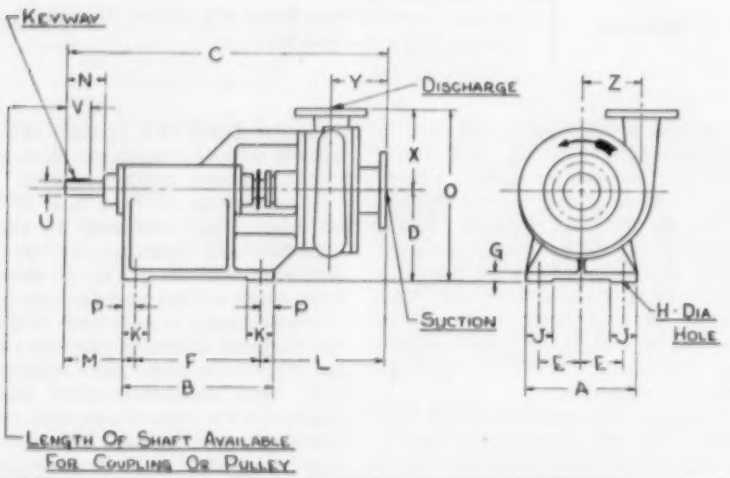
Evaluating the Mechanical Design

The comprehensive thesis, "Evaluating the Mechanical Design of End-Suction Centrifugal Pumps," (*2*) has been reviewed by some pump manufacturers who have little or no quarrel with the contents, especially with the objectives outlined by the author. The

RECOMMENDED LETTER DESIGNATIONS
STUFFING BOX AREA



RECOMMENDED LETTER DESIGNATIONS
BARE PUMP



RECOMMENDED LETTER DESIGNATIONS
PUMP ON BASEPLATE

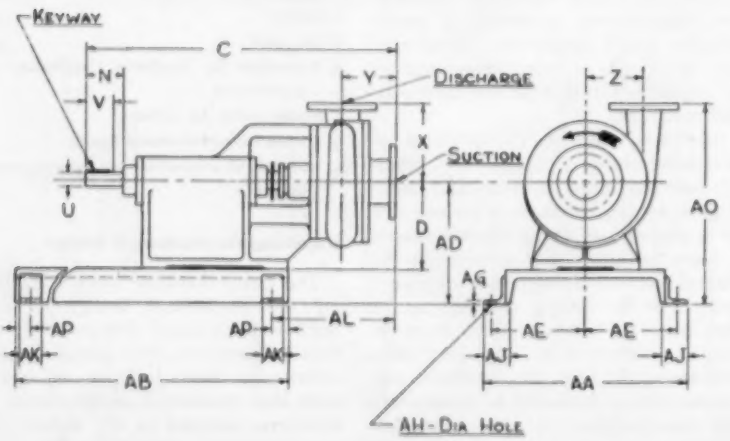


Table A.

	%	No.
End Suction Centrifugal Pumps sold during year 1954—as reported to the Hydraulic Institute up to and including 6-in. discharge	100	128,885
total of these in close-coupled type	54	69,600
total of these in frame-mounted type	46	59,285
For Frame-Mounted Type		
sold to the chemical industry..	21	27,100
sold to other industries	25	32,185

pumps designed to follow the contents and objectives of this treatise would, of necessity, have more mechanical design features than the general line of pumps now offered. In other words, the general line of pumps would have to be "upgraded" and a minimum set of standards evolved for suitable and uniform quality to meet requirements of the chemical industry.

Pump Manufacturers' Analysis of Development

Of great interest to the pump manufacturer is the scope of the B-73 Committee † report (which defines the extent of the activities for this Committee) and especially the part that concerns dimensional interchangeability. A simple example of the problem involved is best illustrated in the electrical industry, in which the dimensions of a 5-hp., 1750 rev./min. motor of major manufacturers are all the same and can be interchanged without any difficulty. The internal construction of the motor varies slightly, depending upon the particular manufacturer's engineering and manufacturing ability.

Dimensional interchangeability for pumps means that for any particular head and capacity range all manufacturers would offer a pump that dimensionally would be interchangeable with pumps made by other pump manufacturers, the only variance being in the hydraulic and internal construction. This will ultimately result in a completely new line of pumps, which will probably be a compromise between all designs, and will incorporate the engineering and quality standards that will evolve from the efforts of the B-73 Committee.

Before any pump manufacturer will embark on this costly program, he will investigate to the fullest extent the following features:

a. engineering and design
b. models and testing

† B-73 Committee is Subcommittee of A.S.A. Sectional Committee (Centrifugal Pumps for the Chemical Industry).

c. patterns—will they be made of wood or metal?

d. tools—will they be made for low or high production?

e. printed material necessary for sales promotion, including bulletins, price sheets, and dimension sheets

f. inventory of stock parts, including choice of materials of construction

The above list is not a speculative one; these items are the actual ones that must be investigated and evaluated in any new development plan as a plain and simple matter of economics. It is estimated that designing the pumps necessary for the operating, engineering, and quality standards specified, and completing the program will cost each pump company approximately $200,000.

At the present time there is absolutely no way of knowing exactly what the final design of pumps suitable for the chemical industry will be. That investigation and decision rest with the A.S.A. Sectional Committee B-73.

Responsibility of Chemical Industry

If the pump manufacturers are to proceed with the redesign of pump units and base their engineering design on the "upgraded" evaluation of the mechanical and quality standards, then it follows—and rightly so—that the chemical industry will have to assume a dual responsibility or co-sponsorship in the support of this over-all program.

Judging by previous experience, a divergence of opinion exists in the chemical industry concerning the various aspects of a centrifugal pump. From the pump manufacturer's viewpoint, these differences of opinion between chemical companies, between departments within the same chemical company, and between plants within the same chemical company must be resolved so that there will be a singleness of purpose in the

It is the responsibility of the **pump manufacturer** to produce pumps with adequate hydraulic and mechanical design at a level desired by the user. Also, the pump must be assembled properly with good workmanship and materials of construction.

It is the responsibility of the **pump user** to:

(a) install pumps properly.

(b) operate them within the limits determined by the pump manufacturer.

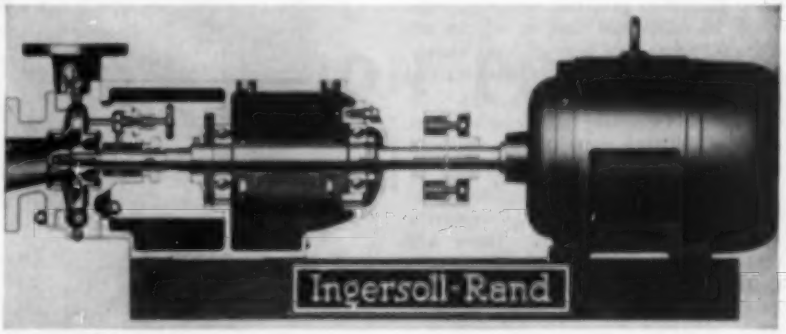
(c) maintain them in accordance with the manufacturers' recommendations.

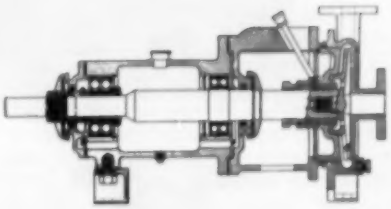
(d) repair them properly.

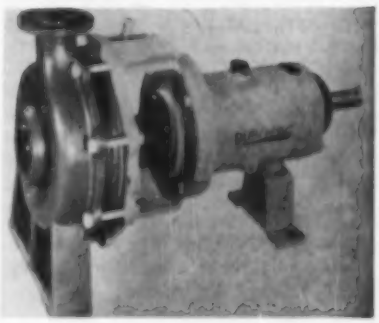
D. S. Ullock—*Chem. Eng. Progr.* 51, No. 5, 207, (1955).

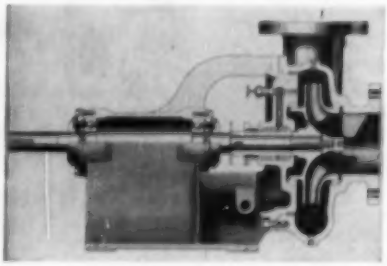
The photographs of base and close-coupled pump mountings on this and the following page illustrate the author's point that the liquid end of the pump does not know how it is mounted—a fact basic to the whole concept of interchangeability.

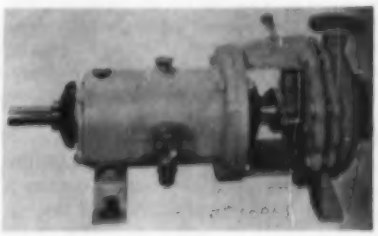
STANDARDIZATION OF PROCESSING EQUIPMENT

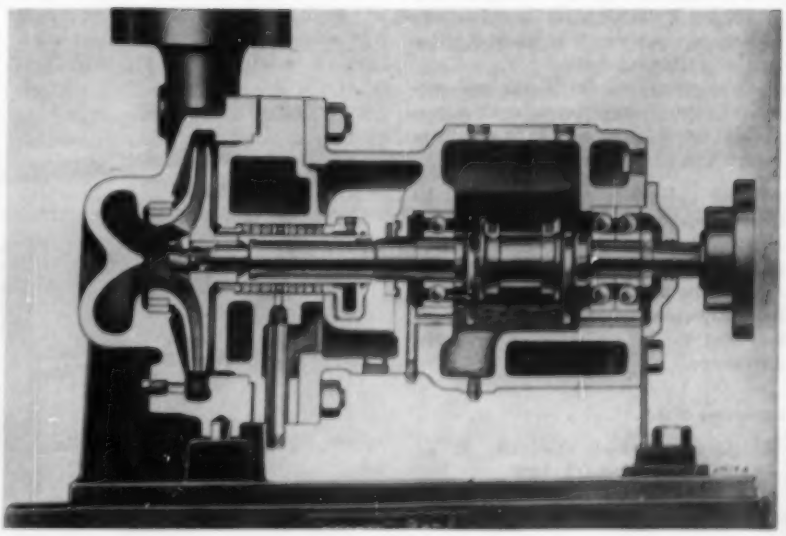












far-reaching program of developing standards for pumps.

In addition, one can envision an extended period of change-over within the companies interested in new pumping units. In new construction there should be no particular problem, except to convince all concerned that it will be an advantage from an over-all cost standpoint to be completely satisfied with the standardized line of equipment. In expansion of existing plants or replacement of existing units, the design and manufacture of a standardized line of pumps will not be an immediate solution to all problems of high inventories or high replacement costs. There will still be a demand for duplication of existing equipment, and high costs connected with such demands will remain. These high costs will continue for several years and the changeover to standardized units will be a long and gradual evolution.

Conclusions

What, then, are the main objectives for which the pump industry will be striving in this over-all program?

a. Design, engineering, and quality standards which will be acceptable to consumers in all classes of industry. Such industries include:

1. chemical
2. industries pumping the chemicals manufactured by chemical industry
3. paper
4. petroleum
5. electroplating

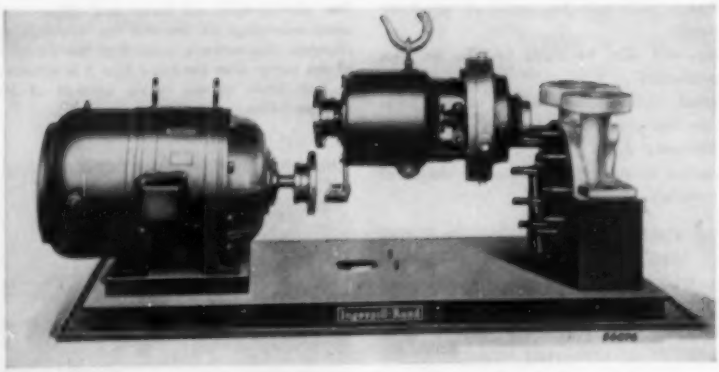
b. Interchangeability of the liquid ends —or pump ends—between the frame-mounted and close-coupled construction. Quantity production of the liquid ends—or pump ends—in order to justify the initial investments in pattern equipment, tools, and inventory of stock parts, required for low manufacturing costs.

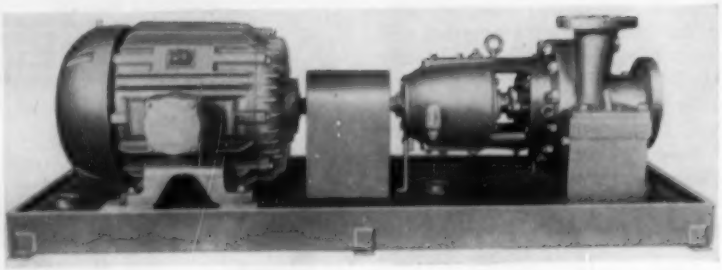
c. Developing standards for end-suction, single-stage centrifugal pumps which will be acceptable in every respect to all classes of industry.

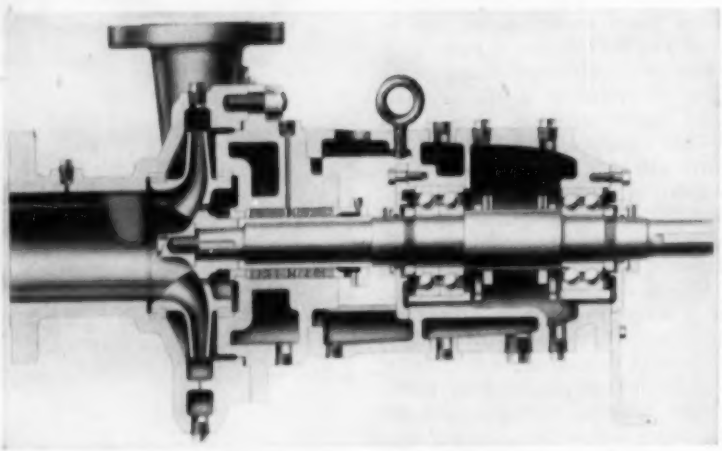
These objectives can be attained by close cooperation, exchange of ideas, and complete surveys of the needs of all types of industries, so that the final result will be a set of standards that will be acceptable in design, construction, and cost to the majority of industrial consumers.

Literature Cited

1. Hydraulic Institute, New York, 10 ed. *Standards* (October 1, 1955).
2. Ullock, D. S., *Chem. Eng. Progr.*, **51**, No. 5, 207 (1955).







In spite of there being no readily evident common relation between such diverse operations as crushing, boiling and dropwise condensation, and crystallization, all do represent the creation of new interfaces. These involve the formation of a nucleus, and then a growth process. How this concept can be applied to size reduction is discussed.

SIZE REDUCTION as a NUCLEATION PROCESS

W. H. C. Simmonds | Dominion Tar & Chemical Company, Montreal, Canada

The rapid growth of chemical engineering and its success in handling problems of great variety have resulted, in no small degree, from the development of methods utilized broadly in the fields of heat and mass transfer, and fluid flow. Among methods under consideration or development which may be expected to have a profound effect on the future of chemical engineering, is one which utilizes the concept of nucleation as applied to certain unit operations.

As a matter of definition, nucleation can be regarded as the common starting point which might go far in merging such diverse operations as crushing, boiling and dropwise condensation, crystallization, and the formation of sprays and emulsions. In spite of there being no readily evident common relation between these operations, all do represent the creation of new interfaces which involve: first, the formation of a nucleus, and second, a growth process. This is nucleation.

The factors governing nucleus formation and growth are not necessarily identical. One would therefore not expect the methods of dimensional analysis to be successful in explaining them.

Nucleation involves the creation of a new phase. The physical picture of nucleation involves mechanisms which depend on the nature of the phase. Table 1 shows how nucleation as an overriding concept binds together many diverse operations involving the generation of the new phase.

The older viewpoint classifies these processes according to the nature of the energy producing the change, that is, electrical, mechanical, thermal, and chemical. However, the physical mechanism controlling the formation of a gas bubble does not depend on the nature of the energy supply and, hence the idea of nucleation embraces all these processes as examples of a single mechanism (*28*).

Irreversibility

Nucleation processes are irreversible and occur when finite potentials exist. They cannot be reversed by infinitesimal changes in potential. For example, vaporization of a liquid can occur reversibly. Production of vapor bubbles within a liquid by boiling is an irreversible process. Irreversible processes produce final results which depend on the order in which the change is carried out compared with reversible processes which are independent of the order of change. For example, in size reduction a hard blow will fracture a solid. The fracture once started cannot be reversed and the final shape of the fragment depends upon the point where the fracture began. However, if a sufficient number of crystals are fractured, a definite particle-size distribution pattern

Table 1.—Methods of Classifications of Various Processes

Process	Physical			Chemical	
	Discharge of a gas at an electrode	Release of a gas from solution at surface of a solid by pressure reduction	Boiling of a liquid on a hot surface	Evolution of a gas by solution of a metal	Decomposition of a liquid into a gas by a metal
Classification					
Traditional	Electrochemistry	Cavitation	Heat transfer (ebullition)	Inorganic chemistry	Catalysis
Nucleation	..... Formation and growth of bubble nuclei				

Table 2.

ACTUAL PROCESS

↓

Ideal irreversible	⟷	Reversible
potentials retained		potentials eliminated
geometry simplified		geometry retained
rate of change—finite		rate of change—nil
result dependent on order of operations		result independent of the order of operations

will emerge. Similar arguments hold the same as obtained for the formation of bubbles, drops, crystal nuclei, etc.

A single event is not reproducible, but when a sufficient number of events is considered, the statistical nature of the irreversible change becomes more apparent. In irreversible processes material and energy balances become statistical statements also, and take the form shown in Equation (1).

$$M = m_1 + m_2 + \ldots = \Sigma m_i \qquad (1)$$

An energy balance made on a system undergoing change will exhibit a statistical form showing the percentage of energy which is retained by the matter in each of the size grades.

In an irreversible process the energy balance cannot be written by the simple equation (*8*)

$$W = E_s + Q.$$

An additional term must be added to cover the irreversible nature of the process. Thus, the entropy of the system is the sum of the entropies of its parts that can change by two mechanisms (*14*):

1. interaction with the surroundings
2. changes within the system

That is, $dS = d_eS + d_iS$ wherein subscript e refers to the external portion of the system and i refers to the internal portion.

If heat is absorbed by the system from its surroundings at an absolute temperature, T, then

$$d_eS = dQ/T$$

If the changes are conducted reversibly, $d_iS = 0$; if they occur spontaneously, $d_iS \neq 0$, and the system and the surroundings cannot both be returned to their original states. In all practical problems $d_iS \neq 0$, so that $dS > d_eS > dQ/T$ and

$$dS = dQ/T + d_iS$$

This means that energy is liberated within the system during the irreversible change and must be included in the energy balance, so

$$W + E_{Ir} = E_s + Q \qquad (2)$$

The practical consequences of this are twofold. Efficiencies are given by $E_s/(W + E_{Ir})$ and not by E_s/W, and although the term E_{Ir} would seem to be numerically small compared with W, yet in the case of size reduction it may well be of the same order of magnitude as E_s, the useful surface energy produced.† Calculations or experimental determinations of E_{Ir} would be of considerable interest to see how important this term is.

The Ideal Irreversible Process

A standard of reference for irreversible changes should be established because the absolute efficiency of such processes, as evaporation, distillation, etc., is very low by the standards of classical thermodynamics. It should be possible to construct an irreversible process where only the essentials have been retained (that is, the potentials or driving forces in the original system must be retained since they are the origin of irreversibility.) The geometry of the system should be postulated as the simplest possible to permit the process to occur. The scheme (see Table 2) represents a comparison of an ideal irreversible process with a reversible process. Note that the reversible process depends on only the initial and final states of the system. It is independent of the order in which the changes are carried out, independent of the size and shape of apparatus, and of the rates of change.

An ideal irreversible process does, however, contain finite potentials, rates of change, and the effect of the order of operation. It contains these in a system employing the simplest possible geometry. Such would serve as the base comparison for machines and show the loss of efficiency due to running the process at a finite rate.

The difference between the reversible process and the ideal irreversible process gives the loss in efficiency by conducting the process at a finite rate; this loss is unavoidable. The difference between the ideal irreversible process and the performance of an actual machine shows the additional losses due to imperfections in the design of the machine and hence the scope for improvement. It is clear that such a division of the losses would be of great help to chemical engineers.

Example—Ideal Irreversible Process

An example where this approach is, in effect, already being employed is fluid flow through a pipe. The simplest case is that of a Newtonian liquid flowing isothermally through a perfectly smooth, circular pipe of infinite length. Under these conditions the properties of the fluid and the flow conditions are completely specified. This establishes a standard in terms of which the flow through rough pipes of finite length and the effect of entrance and exit conditions can be measured.

The question then arises as to whether there is an ideal irreversible process or a whole series of them depending on the model chosen. This can be answered only by a complete analysis of liquids with various properties flowing through conduits of differing sizes and shapes, by the methods of irreversible thermodynamics (*6, 7, 25*). Such an investigation might lead to the establishment of criteria for the choice of ideal irreversible processes, criteria which are not obvious at the present time. In the meantime, standards such as the one given above for fluid flow and the one suggested below for size reduction seem to afford profitable starting points.

Size Reduction

Crushing and grinding is an operation of immense practical importance but one of the less satisfactory items in the chemical engineering repertoire. The present status has been reviewed by Piret (*24*). Progress is being made in the practical applications (*4*), but the basic problem of why so much energy produces so small a result remains.

The ideas presented above suggest a new approach to this problem and this is discussed from both the experimental and theoretical points of view.

EXPERIMENTAL APPROACH

In recent years experimental studies of size reduction have been made and methods for analyzing the product have been greatly improved, but the position in regard to the energy balance is much less satisfactory. So far as the author

† A similar case recently has been established in the falling rate period of drying where the transfer of a numerically negligible quantity of heat has been found to control the temperature of the drying solid and hence the temperature driving force (29).

knows, the four quantities involved—the work input, the heat evolved, the increase in surface energy, and the energy liberated within the system—have never been measured for the same experiment.

It might be possible to do so in the case of *Prince Rupert's drops*—drops of molten glass solidified by sudden quenching and in such a state of locked-up stress that they disintegrate under the lightest touch. A disintegration could be carried out in a calorimeter in this case since the mechanical work input required is small.‡ Only by keeping the value of W as small as possible does it seem feasible to measure the order of magnitude of E_{fr} from the sum of the terms $(E_s + Q - W)$ (*cf. 26*).

If carefully conducted, this experiment should show that the release of internal energy may play an important part in fracturing. It underlines Bond's (*4*) contention that size reduction in practice includes every operation from drilling and blasting the rock onwards, i.e., any stresses left in the ore or introduced in processing will influence its behavior during the subsequent crushing and grinding.

The next point is the kinetics of size reduction. Looked at from the nucleation viewpoint, size reduction is a process in which crack nuclei are formed and the cracks then grow to form cleavage surfaces. The rate-controlling step may therefore be either the formation of the crack nuclei or the growth of the fractures. However, there is little experimental data for this kind of analysis except in the case of glass (*22, 27*).

The conclusion is that there is room for some different kinds of experiments for a fuller understanding of size reduction.

THEORETICAL APPROACH

The idea here is to treat the formation of crack nuclei as an activated rate process and the resulting subdivision as an energy distribution problem governed by the physical properties of the solid applied to the model termed the ideal irreversible process. The ideal irreversible process proposed for size reduction is:

a. to stress instantaneously the original particles independently under constraint beyond the point of failure.

b. to release the constraint instantaneously, and to allow the system to reach equilibrium in its new state at the initial temperature.

This separates size reduction into two essential and independent steps: energy transfer from an external source to the solid, and the subsequent fracturing process within the solid.

1. Material Balance

The statistical material balance Equation (1) is

$$k_p D^3 = a_1 k_1 \rho_1 d_1^3 + a_2 k_2 \rho_2 d_2^3 + \ldots . \quad (3)$$

For a homogeneous solid, the shape of which is independent of particle size, and a product which is analyzed in a series of size grades following a $\sqrt{2}$ scale, Equation (3) reduces to

$$r^3 = \left(\frac{D}{d_1}\right)^3 = a_1 + a_2 \cdot 2^{-3/2} + a_3 \cdot 2^{-3} + \ldots . \quad (4)$$

In words, the reduction ratio, r, a dimensionless ratio, is equal to a set of coefficients governing the size distribution and the problem becomes one of determining the values of these coefficients.

2. Energy Balance

The change in energy of a cube of side D subdivided into a number of cubes of side d is

$$E_1 = D^3 e_1 + 6D^2 e_2 + 12D e_3 + 8e_4 \quad (5)$$

$$E_2 = \left(\frac{D}{d}\right)^3 (d^3 e_1 + 6d^2 e_2 + 12d e_3 + 8e_4) \quad (6)$$

so that

$$E_2 - E_1 = 0 + 6e_2\left(\frac{1}{d} - \frac{1}{D}\right) + 12e_3\left(\frac{1}{d^2} - \frac{1}{D^2}\right) + 8e_4\left(\frac{1}{d^3} - \frac{1}{D^3}\right) \quad (7)$$

in which e_1, e_2, e_3, and e_4 refer to the energy per unit volume, unit surface, unit edge and corner respectively and are in different units accordingly.

Equation (7) shows that there are four terms to be considered. The first term dealing with the internal energy of the solid shows zero change for a perfectly elastic solid, but there is increasing evidence that deformation of the solid occurs (*1, 11, 12*). The second term represents Rittinger's law, namely that the power consumption is proportional to the fresh surface area produced, and the third and fourth terms refer to the increase in edge energy and corner energy, respectively. Equation (7) shows that Rittinger's law can only be expected to hold when the other terms are small in comparison with the second one.* This is less likely to be true when the particle size becomes very small, and when the product of size reduction has stepped, irregular or hackled rather than plane surfaces (*27*).

Substituting Equations of the form (5) into Equation (3) to find the value of E_s, the net energy absorbed in forming the new surfaces, edges, and corners, one obtains

$$E_s = [a_1(d_1^3 \cdot e_1 + 6d_1^2 \cdot e_2 + 12d_1 \cdot e_3 + 8e_4) + a_2(d_2^3 \cdot e_1 + 6d_2^2 \cdot e_2 + 12d_2 \cdot e_3 + 8e_4) + \ldots\ldots] - [D^3 \cdot e_1 + 6D^2 \cdot e_2 + 12D \cdot e_3 + 8e_4] \quad (8)$$

The first term in the brackets cancels for an elastic solid. Assuming a $\sqrt{2}$ progression of size groups, Equation (8) becomes

$$E_s = 6d_1^2 \cdot e_2(a_1 + a_2 \cdot 2^{-2} + a_3 \cdot 2^{-4} + \ldots - r^2) + 12d_1 \cdot e_3(a_1 + a_2 \cdot 2^{-3/2} + a_3 \cdot 2^{-3} + \ldots - r) + 8e_4(a_1 + a_2 + a_3 + \ldots - 1) \quad (9)$$

Since the energy liberated during the size reduction is also a function of the number and size of the particles produced, Equation (9) can be written in the form

$$W - Q = (E_s - E_{fr}) = F(a_1, a_2, a_3 \ldots)(d^3 e_1, d e_2, e_3, e_4) \quad (10)$$

provided no plastic deformation occurs.

3. Crack Nuclei

The next step would be to set up an expression for the rate of formation of crack nuclei by the use of the theory of activated rate processes. However there are difficulties. Unlike phenomena such as chemical reactions, diffusion, viscosity, electrical conductivity, etc., there are two sources of energy available for the formation of a crack nucleus, even in the case of an initially stress-free solid. There is the thermal energy corresponding to the familiar temperature-dependent exponential term, $e^{-H/RT}$, and also the energy supplied from the external source which is temperature-independent.

This problem has been tackled from the activated rate process point of view for metals (*23, 33*) and glass (*3,5*), but in both these fields the chief interest lies in the conditions which just lead to fracture, for example, fatigue failures and the slow development of cracks in glass. The results are therefore given in the form of the time required for the first crack or flaw to form and continue to grow. The conditions are very different in size reduction in which a large excess of energy above that required to produce a single crack is applied, and it is possible that under these conditions a simpler form of expression for the rate of formation of crack nuclei can be derived.

4. Subdivision

Given the number of crack nuclei formed, the problem is to determine the number and size of the particles formed consistent with the energy balance, Equation 10, and the physical characteristics of the solid, *i.e.*, to select from all the mathematically possible modes of subdivision those which are physically permissible. In the case of crystalline materials, fracture is known to occur along certain crystallographic planes (the [100] plane in the case of the alkali halides) but for noncrystalline materials such as quartz and glass the fracture is

‡ If size reduction occurs in vacuo, the energy liberated during the formation of clean, fresh surfaces would be measured; usually a gas or liquid is present and the energy change will then include the heat of wetting of the freshly formed surfaces.

* Bond has shown that if a power consumption law intermediate between volume dependence and surface area dependence is assumed, the total work useful in breakage is inversely proportional to the square root of the diameter of the product, directly proportional to the length of the crack tips formed, and directly proportional to the square root of the surface area formed. He has shown that this "Third Theory of Comminution" gives good agreement between theory and practice in commercial size reduction (*4*).

not crystalline in accordance with their nonregular structure (*23*). A solution therefore requires more data on modes of splitting, *i.e.*, of the shape of the products of size reduction as well as the particle-size distribution and the surface area.

Discussion

If there were no physical restrictions on the ways in which subdivision occurs, Equations (4) and (10) could be solved by summing all the mathematically possible modes of subdivision with the minimum assumption that they are all equally probable. This would be difficult, and attempts have been made to simplify matters by applying the methods of mathematical and physical statistics (*15*). For example, Epstein (*10*) has shown that the assumptions of constant probability of breakage and of distribution of weight of particles in a single breakage event, both independent of particle size, lead to the logarithmico-normal size distribution. Griffiths (*13*) went a step further by applying the methods of statistical mechanics and derived the Rosin-Rammler equation, Gaudin's law, and the log probability relation on the assumption that the distribution obtained would be the most probable one. No proof was given that this condition holds for irreversible processes and he also ignored the energy liberated within the system during the change. The basic ideas of chemical kinetics and thermodynamics are being applied to size reduction by Hüttig and Theimer (*17, 18, 19, 20, 2*). Their attack on the problem follows from the realization that size reduction represents a balance between a crushing and grinding action and a sintering and agglomerating action. Their development is based on the formal analogy of this with chemical kinetics, and they have suggested a number of ways of analyzing the performance of crushing machines.** It will be seen that these treatments, whether mathematical or physical analogies, are equivalent to restricting the values of the coefficients, a, in Equation (4).

Conclusions

The question then arises as to what practical conclusions can be drawn from the nucleation approach. The answer seems to be to use rate process theory to find the conditions of maximum "brittleness" of the substance to be ground, i.e., to see how the constants of the rate equation change under different conditions and to use this information to reduce power consumption. For example, the effect of temperature is known to be important, e.g., in the brittle and notch-sensitive behavior of certain steels (*23*), and in the case of natural rubber which becomes brittle at low temperatures. Surface conditions affect the strength of glass (*30*) and are claimed to have effects with other substances (*2, 9, 21*), while the development of internal stresses by heat treatment is commonly used to facilitate the grinding of quartz. These possibilities deserve reexamination.

** The fact that different processes follow the same kinetic law does not necessarily mean that they possess the same mechanism. It is unlikely that radioactive decay, first-order chemical reactions, and certain size reductions proceed by the same mechanism despite their mathematical similarity. The experimental evidence adduced is open to criticism since sieving was used to determine particle-size distributions (*16*), and the reproducibility and accuracy of the constants in the theory have not been shown.

Acknowledgment

The author is indebted to D. W. Oakley and J. C. Gartshore for their helpful comments, and to Professor Burstall, Kings College, Newcastle-on-Tyne, England, for his encouragement.

Notation

D = initial size of particles
d_i = particle size after size reduction
E = energy
E_{ir} = energy liberated within system as result of an irreversible change
E_s = surface energy
k = shape factor
M = initial weight of matter
m_i = weight of matter in size grade i
Q = heat evolved
r = reduction ratio
S = entropy
T = absolute temperature
W = external work done on system
a_i = number of particles in size grade i
ϵ_1 = energy/unit volume
ϵ_2 = energy/unit surface
ϵ_3 = energy/unit edge
ϵ_4 = energy/corner site
ρ = density

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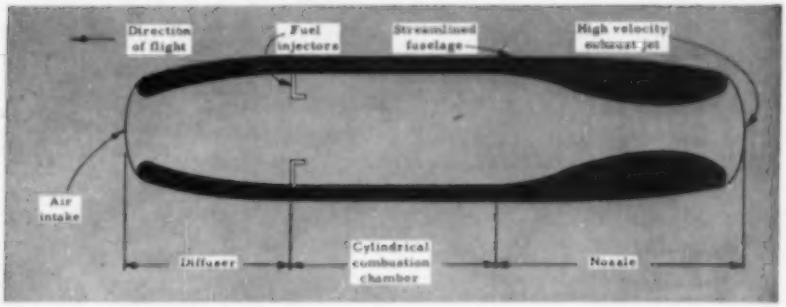

Fig. 1. Schematic diagram of ramjet.

The basic types of jet propulsion devices in use today—ramjet, pulsejet, turbojet, propellerjet and rocket—are briefly discussed. The successful operation of each of these power plants is centered on precise control of many operations, many of which are more familiarly known to the chemical engineer under the generic term of unit operations. With the rocket motor as a specific example, the problems associated with fluid flow, flow through orifices, thermodynamics, heat transfer, combustion kinetics, ignition, exhaust gas disposal, and materials selection are described. Finally, it is shown that the principle employed in jet propulsion may offer interesting possibilities for the manufacture of chemicals involving certain types of reactions.

CHEMICAL ENGINEERING in JET PROPULSION

Louis R. Rapp

Reaction Motors, Inc., Denville, New Jersey

High-speed jet propulsion is a successful development of scientific technology, yet the number of unsolved problems attached to jet propulsion are tremendous. Although it is true that many of these problems are associated primarily with the mechanical and aeronautical engineers, what may be a surprisingly large number are directly associated with the chemical engineer. This fact is presently overlooked by many in the field of chemical engineering.

Jet Propulsion

In accordance with various texts on the subject, jet propulsion is defined as a means of locomotion whereby a reaction is imparted to a device by the momenta of ejected particles. The fundamental principle of any jet propulsion device was formulated by Sir Isaac Newton in 1687; that is, action equals reaction.

Essentially, there are two types of jet propulsion: ducted propulsion and rocket propulsion. Ducted propulsion is a process wherein the ambient fluid is ducted into the device and accelerated to greater momentum, either by mechanical or thermal means, and then exhausted. Rocket propulsion, on the other hand, is a system in which all the matter is stored within the device prior to its ejection. Obviously, by definition, ducted propulsion encompasses a much larger variety of devices than does rocket propulsion.

RAMJET OR ATHODYD

The aimplest, schematically, is the ramjet or athodyd shown in Figure 1. (In the event that the ambient fluid or operating medium is *water*, this device is known as a *hydroduct*). Ambient air enters and has its velocity energy converted to static or ram pressure by means of a diffuser. It passes into the combustion section wherein fuel is burned continuously in air and the heated gases are ejected at high velocity at the rear of the duct to form a jet. This device is *continuous* firing, operating with a *continuous* flow of air. It operates at a relatively low chamber pressure and its performance is contingent on the ram pressure of ambient air. This latter condition implies that

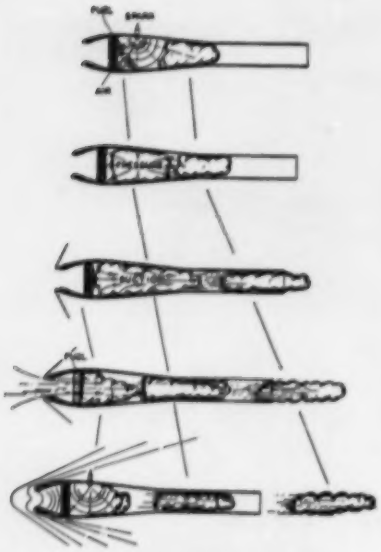

Fig. 2. Operating cycle of pulsejet.

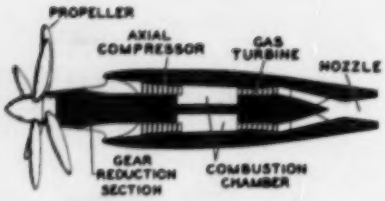

Fig. 5. Schematic of propellerjet.

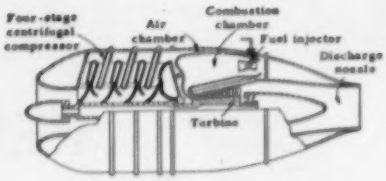

Fig. 4. Schematic diagram of turbojet.

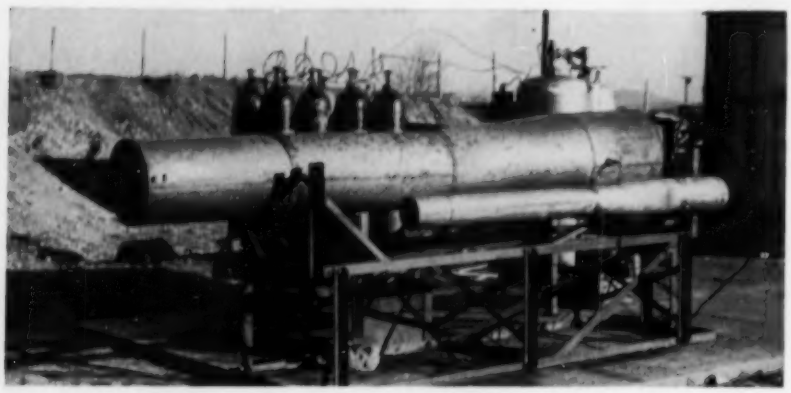

Fig. 3. Exterior view of pulsejet.

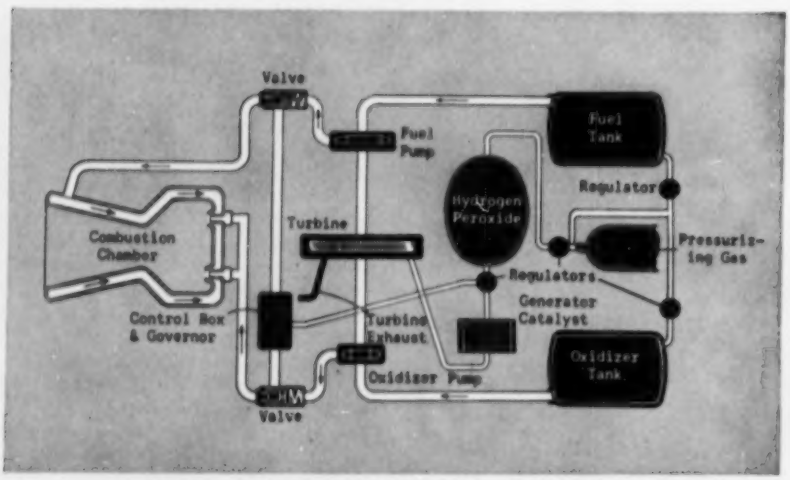

Fig. 6. Schematic of typical liquid rocket engine.

it is inherently a high-speed device; in fact it is estimated that a minimum of 300 m./hr. is required to operate subsonic ramjets.

PULSEJET

A pulsejet works intermittently. Typical of this device are the aeropulse (for air) and the hydropulse (for water); the general functioning is shown schematically in Figure 2. In the forward end of the duct are valves opening inwardly against spring pressure. In flight, air is forced into the duct by ram pressure forcing the valves open. Fuel is supplied into the combustion chamber and the fuel-air mixture ignited with a spark plug or other device. Combustion pressure closes the valves and the air and combustion products are ejected from the duct. This reduces the pressure in the chamber and allows ram air to open the valves and restart the cycle. The frequency of the firing is dependent upon the natural frequency of the duct. The German V-1 "buzz bomb" was powered by a pulsejet. Figure 3 is an exterior view of two different size pulsejets developed at Reaction Motors, Inc.

TURBOJET

The turbojet is a slightly more complex duct system. This device, illustrated in Figure 4, does not depend upon ram air for its operation; however, the ram air does affect its performance. The air entering the unit is compressed by an air compressor, and passed into a combustion chamber where it is heated by combustion with a fuel. The products are expanded through a turbine and then discharged at a high velocity through a nozzle. The turbine, of course, is used to drive the compressor. The specific fuel consumption of this device is lower than that of either the ramjet or pulsejet.

PROPELLERJET

A modification of the turbojet is the propellerjet, illustrated in Figure 5. General operation is quite similar to the turbojet with the exception that the gas turbine, besides driving the compressor, also drives propellers. This system produces higher operating efficiencies at lower velocities than does the turbojet.

It should be emphasized that the picture of the various types of duct propulsion just given is very much oversimplified.

ROCKET

Rocket propulsion is a system wherein the matter to be ejected is stored within the device. The propelling action of a rocket motor is derived from the generation of a large quantity of gas by the chemical reaction of suitable propellants within the rocket motor. Figure 6 is a diagram of a typical liquid propellant rocket motor. The flow sheet of this device can be followed thus:

A small amount of pressurizing gas is used to prepressurize the fuel and oxidizer tanks as well as the propellant (hydrogen peroxide in this case) to drive the gas turbine. To start the system, a valve is opened which allows the hydrogen peroxide to pass through a regulator to a catalytic decomposition chamber; the hot gases produced are expanded through the turbine which, in turn, is used to drive the fuel and oxidizer pumps. The fuel and oxidizer pass through their respective regulator valves into the rocket combustion chamber where they are ignited. The combustion products now at relatively high temperatures and pressures are subsequently expanded through a DeLaval-type nozzle (converging-diverging), producing the thrust.

Pressures produced by the combustion process are governed by the chemical characteristics of the propellants, the rate of consumption, and the cross-sectional area of the nozzle throat. The function of the nozzle is to convert the chemical energy of the propellant gases into kinetic energy.

Figure 7 shows the 6,000-lb.-thrust engine of Reaction Motors which was designed, developed, and built for use in the Bell Aircraft experimental rocket airplane. This engine, employing alcohol and liquid oxygen as propellants, successfully powered the Bell X1 at speeds in excess of 1,600 m./hr. The engine consists of four 1,500-lb.-thrust cylinders capable of individual or simultaneous operation. Figure 8 illustrates the engine installed in the Bell aircraft. To illustrate the power of the jet, Figure 9 shows a small "gopher" hole which was produced by a 30-sec. firing of a 6,000-lb.-thrust engine at an angle of 30 degrees downward.

In comparison with the liquid rocket motor, the solid rocket motor is relatively simple. It consists of a simple cylinder filled with a solid charge of fuel and oxidizer which when ignited produces high pressure gases which are, in turn, ejected through a DeLaval nozzle (see Figure 10).

In addition to these basic types of jet propulsion devices, there are other devices known in the jet propulsion field such as the ramrocket or the turborocket, but they are merely modifications or combinations of the basic systems and therefore will not be considered here.

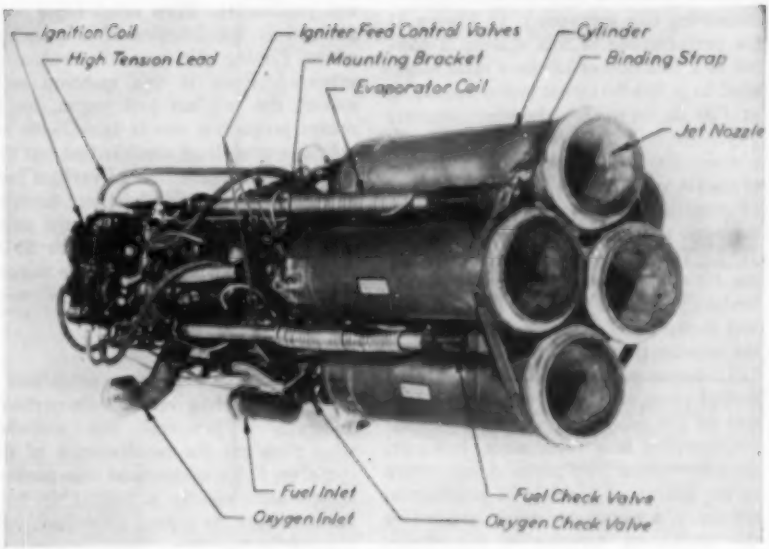

Fig. 7. RMI 6000-lb. thrust unit.

Each of the propulsion systems considered employs the same basic principle of operation, namely the conversion of chemical energy to kinetic energy; each employs a combustion process as the source of chemical energy coupled with a mechanical device, whether it is a turbine or merely a DeLaval nozzle, to convert this chemical energy into kinetic energy or mechanical energy. To the chemical engineer, perhaps the more intriguing power plant is the rocket, for with this system an entirely new set of problems is presented with each change in propellant combination. In the ducted propellant systems at least one of the components, the oxidizer, is fixed.

Rocket Engine as a Unit Process

If one looks at the over-all rocket propulsion system, one can see that it can easily be considered a unit process involving a variety of unit operations. It is true that the oxidation of hydrocarbons with nitric acid is generally considered to be a relatively simple process; however, for propulsion systems, this becomes a critical unit process involving precise control of many of the unit operations involved.

Fig. 8. 6000-lb. rocket installed in aircraft.

Fig. 9. Hole from 6000-lb. thrust engine firing.

FLUID FLOW

Consider, for example, the performance obtainable from the propellant combination, white fuming nitric acid and JP-3. (JP-3 is a hydrocarbon fraction something like kerosene.) In Figure 11 the performance of this system is plotted as a function of mixture ratio measured in a 500-lb.-thrust motor operating at 700 lb./sq.in.abs. chamber pressure (*1*). Here it can be noted that the specific impulse, defined as the pounds of thrust available per pound per second of propellant flow, varies markedly with the ratio of oxidizer to fuel, WFNA to JP-3. The need for precise control of the ratio of oxidizer to fuel in the combustion process is obvious. Performance and thrust level are also a function of the combustion pressure (see Figure 12); hence one sees the need of controlled rates of flow as well as the control of the ratio of flow of propellants.

Controlled flow rates alone, however, do not produce high performance; there is the additional problem of combustion efficiency, a parameter much affected by the method of injection of propellants. Here is a basic unit operation, the characteristics of which vary with every propellant combination and operating condition. Consider, for example, a few of the questions which face the rocket scientist daily. Should the injector be designed for efficient liquid-phase mixing or gas-phase mixing? What type of injector should be used when one propellant is an extremely low boiling liquid, such as oxygen, and the other a relatively high boiling liquid such as aniline? Which type of injector induces most efficient combustion—impinging jets, like-on-like, shower-head, cone spray, or any other type which is available. How does one successfully scale-up an injector satisfactory in a 5,000-lb. thrust engine for a 50,000-lb.-thrust engine? Unfortunately, there are no simple answers to these questions, for after many years of research many still remain unanswered.

COMBUSTION KINETICS

If the assumption is made that the desired flow rates are obtained and a somewhat suitable injector has been designed, there remains another important parameter untouched, that of combustion kinetics. Thus far clairvoyance seems to be as successful in this regard as engineering. The problem of limited space in the missile or vehicle is ever present and therefore it is imperative that the reaction be accomplished in the smallest possible space. Thermodynamics indicate how much energy is obtainable from a system, free energy data will tell if the reaction will occur, but who can predict exactly how it will go or how fast it will go? As generally known, the kinetics of the relatively simple combustion of methane and air has been studied for over a decade, but the results are still a subject of study and publication. How much more complicated is the kinetics of a gasoline-white fuming nitric acid combustion process? Even if this question were solved, the job has just begun, for in rocket propulsion one is faced with not only one propellant combination but any number of combinations of various fuels and oxidizers. Combustion kinetics, when viewed in the light of the problems yet to be solved, appears to be virtually untouched despite the numerous scientists now engaged in this field.

HEAT TRANSFER

If it is conceded that a propellant is available which gives a high performance in a practical size chamber, what then are the requirements of this container? To understand this problem a little more clearly, a look at the basic requirements for a good propellant combination is desirable. Figure 13 contains a few basic equations which apply to the rocket motor such as:

$$F = \frac{WC}{g}$$

Thus the thrust is directly proportional to the flow rate and the effective exhaust velocity. This exhaust velocity can be calculated from the relationship

$$C = \sqrt{\frac{2gk(R)}{k-1}\,T_c\left[1-\left(\frac{Pe}{Pc}\right)^{\frac{k-1}{k}}\right]}$$

where $R = \dfrac{1545}{M}$;

$$C = \sqrt{\frac{2gk}{k-1}\,\frac{(1545)}{M}\,T_c\left[1-\left(\frac{Pe}{Pc}\right)^{\frac{k-1}{k}}\right]}$$

Analysis of these two relationships reveals that the exhaust velocity is directly proportional to the square root of the combustion temperatures and the reciprocal of the average molecular weight of the exhaust gases M. It also increases with the expansion ratio (Pc/Pe) and with a decrease in the specific heat ratio; however, the effect of the latter two parameters is only of minor importance.

It is obvious, therefore, that the search for high performance propellants leads to combinations resulting in high combustion temperatures. Figure 14 contains a list of propellant combinations together with their calculated combustion temperatures with liquid oxygen as the oxidizer. These high temperatures, of course, lead to the problem of heat transfer in the combustion chamber and the nozzle throat area.

Figure 15 shows a curve of the heat transfer data obtained by Zucrow and Beighley (*2*) for the JP-3-WFNA system as a function of mixture ratio. These data were obtained on the system operating at 700 lb./sq.in.abs. chamber pressure. The curves show the heat transfer in the nozzle section, the chamber section, and the over-all heat transfer. Maximum values at the throat were between 5 and 6 B.t.u./sec./sq.in. In this case, since it was an experimental chamber, water was used as the heat transfer medium, however, in actual operations attempts were made to employ one of the propellants as the coolant in what is known as a regeneratively cooled motor. Figure 16 is a typical example of the damage to a rocket chamber and nozzle as a result of malfunction or improper heat dissipation to the coolant.

Many means are employed to overcome the heat transfer problems such as the use of ceramic or other type liners, transpiration, or "sweat" cooling, wherein part of the coolant is bled into the combustion chamber through porous walls, and so forth. It is a simple matter to visualize the difficulties of measuring heat transfer coefficients of 100% nitric acid at its boiling point, or the heat transfer coefficient of some other equally nasty material under similar conditions.

IGNITION KINETICS

But suppose the problems of heat transfer, flow rate control, and combustion kinetics were solved, how does this monster get fired up in the specified time required? This time may vary from a fraction of a second to a few seconds depending on the size of the motor and its intended use. There are means at one's disposal such as a squib, i.e., a powder charge which is set off just prior to propellant flow, or the use of hypergolic mixture, i.e., a propellant combination which ignites spontaneously upon mutual contact, or a spark plug, or some other device. Whatever the source, ignition delay is of utmost importance. One can readily realize the importance when the following example is considered.

Example

Suppose a 50,000-lb.-thrust engine with a propellant combination is to be operated with a 250-sec. specific impulse; this results in a propellant flow rate of 200 lb./sec. to the combustion chamber. Obviously, a second delay in ignition could result in an explosion of 200 lb. of an extremely energetic combination. Actually, ignition must be obtained in the order of a 100 msec. or less to prevent disastrous results.

Figure 17 is a typical example of what in rocket parlance is known as a hard start.

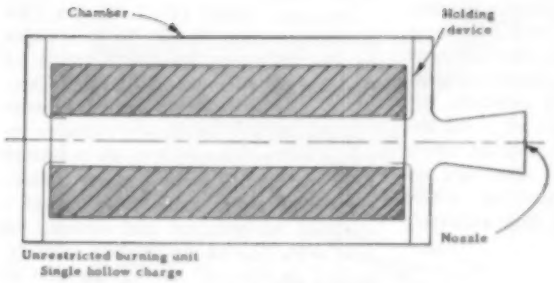

Fig. 10. Schematic of solid propellant rocket.

Performance Relationships for Rocket Engines

$$F = \frac{W}{g} C$$

$$C = \sqrt{\frac{2gk}{k-1} RT_c \left[1 - \left(\frac{P_e}{P_c}\right)^{\frac{k-1}{k}}\right]}$$

$$\text{or } C = \sqrt{\frac{2gk}{k-1} \frac{(1545)}{M} T_c \left[1 - \left(\frac{P_e}{P_c}\right)^{\frac{k-1}{k}}\right]}$$

Fig. 13. Performance relationships for rocket engines.

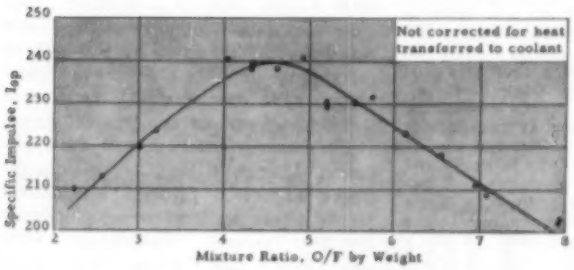

Fig. 11. Performance vs. mixture ratio for WFNA-JP-3 at 700 lb./sq.in.abs. chamber pressure.

Calculated Chamber Temperatures for Various Propellant Combinations using Liquid Oxygen as the Oxidizer

Fuel	Chamber Pressure lb./sq.in. abs.	Mixture Ratio O/F	Chamber Temp. °F.
Gasoline	300	2.5	5470
Alcohol	300	1.5	5250
Ammonia	300	1.4	4950
Hydrogen (l)	340	5.3	5430

Fig. 14. Calculated chamber temperatures for various propellant combinations using liquid oxygen as oxidizer.

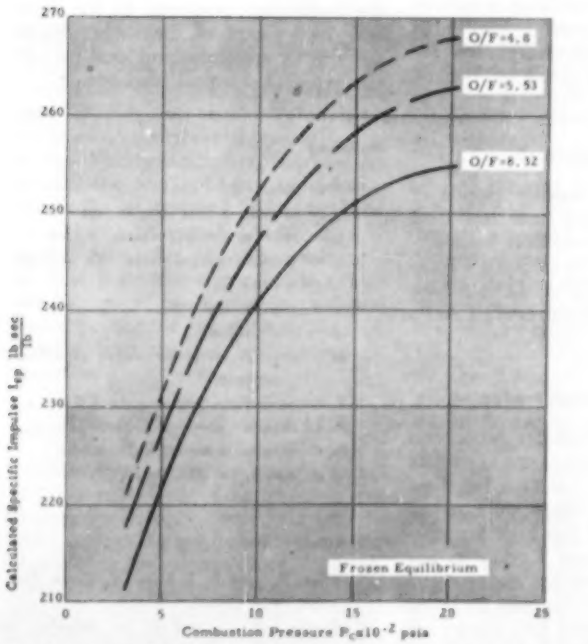

Fig. 12. Average theoretical performance of octane oxidized by WFNA.

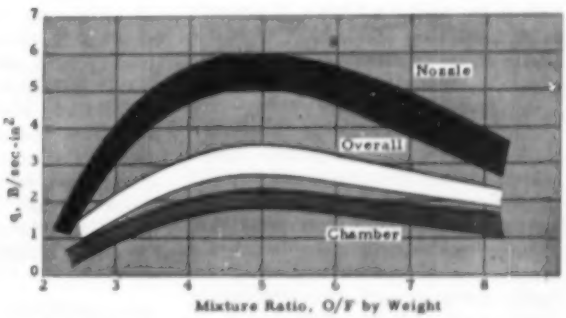

Fig. 15. Heat transfer vs. mixture ratio for WFNA-JP-3 at 700 lb./sq.in.abs. chamber pressure.

Fig. 16. Rocket chamber burnout.

Fig. 17. Chamber damage due to hard start.

PUMPS AND MATERIALS

Only the combustion end of this unit process has been discussed here. What about the other unit operations involved—the development of high-speed pumps for propellant flow, pumps which must operate with extremely corrosive materials such as white fuming nitric acid or high vapor pressure materials such as liquid oxygen? The selection of gasket materials, sealants, lubricants, O-ring materials is a separate problem for each propellant employed. One problem sometimes faced is how to design a pump feed system so that cavitation is avoided when the materials to be used are known to detonate under conditions of adiabatic compression or under conditions more commonly known as "water hammer."

Of course, there are always the problems concerning the material compatibility for the propellant tanks, valves, storage containers, and transfer mechanisms. The problem of extended storage for many of these propellants is sometimes extreme. The design of a low-loss or no-loss storage vessel for highly corrosive and toxic low boiling liquids is a problem which had to be solved before some of the high energy propellant combinations could be utilized.

Fig. 18. Instrument and control panel.

DISPOSAL PROBLEMS

Then again, the problem quite common to many chemical manufacturers is the disposal of effluent or exhaust gas. Of course, with some propellant combinations, such as the alcohol-lox system, this offers no particular concern; however, with some propellant combinations, toxic or extremely corrosive exhaust gases may be ejected from the chamber. This is a real problem where static testing is made in areas not too remote from civilization or where launching must be made from relatively confined areas.

Problem

Assume the static firing of a 50,000-lb.-thrust engine with a propellant combination exhibiting a specific impulse of, say, 250 sec. and the exhaust of which is toxic or extremely corrosive. The duration of the static firing is to be for 30 sec. Simple calculations indicate that we will obtain a flow rate of gases from the chamber of 200 lb./sec. or 6,000 lb. of gas in 30 sec. In addition, by somewhat more laborious calculations, it is found that these gases are moving at supersonic speeds—speeds of 5,000 to 10,000 ft./sec., and at temperatures in the order of 3000° F. One can readily see that this is not going to be easily and economically solved by a simple "off-the-shelf" spray tower. In addition, a water treatment plant may be required before disposal can be permitted.

Fortunately, this sort of problem does not arise every day; however, there are locations in existence today where disposal systems, similar in many respects to that just described, are required.

For those chemical engineers interested in instrumentation, intriguing problems are faced involving a variety of different measurements. Figure 18 shows a panel of instrumentation required for the static firing of one of the larger motors.

SOLID PROPELLANT PROCESSING

The chemical engineering aspects of propellant manufacture have not been touched on because these have been discussed previously ("Small Scale Facilities for Development of Double-Base Propellants," A. T. Camp, *et al.*, C.E.P., 52, 79-F, 1956).

Rocket Cycle in Chemical Production

Transgressing beyond the propulsion aspects of jet propulsion, one considers for a moment other potentials for these high pressure, high temperature power plants. It is realized that high temperatures generally enhance a reaction, unless the activation energy is extremely low, and that certain reactions go faster than others. Also from free energy relationships, one knows that certain reactions are pressure sensitive. From previous discussion the reader should now associate high temperature and high pressure reactions with the rocket engine cycle.

Wise and Baker (*1*) of the Jet Propulsion Laboratories did. In their paper on the "Kinetics of the Fixation of Atmosphere Nitrogen at Elevated Temperatures," they pointed out that kinetically the efficient fixation of nitrogen involves two problems: first, the residence time required to form a given concentration of nitric oxide from air at a specified temperature and second, the rate of cooling of the product gases required to "freeze" the composition of the gas mixture attained at the reactor temperature.

Calculations made by Wise and Baker showed that the equilibrium concentration of nitric oxide was doubled by increasing the reactor temperature from 2400° K. to 2800° K.; however, they were also quick to point out that there was little to be gained by this rise in reaction temperature unless it is accompanied by a corresponding increase in the cooling rate of the product gases.

They also pointed out that the application of the principle of adiabatic, isentropic expansion through a DeLaval nozzle offers an interesting possibility for this process. Calculations have shown that a rate of temperature change in the order of one million degrees Kelvin (1×10^{6}° K.)/sec. is obtainable in the temperature region of interest to the problem of atmospheric nitrogen fixation. In other words, the thermodynamic and kinetic cycles inherent in rocket motor application together with the techniques developed in the study and development of the rocket engine are directly applicable and ideal for certain types of chemical reactions.

Notation

F = thrust, lb.
W = propellant flow rate, lb./sec.
C = effective exhaust velocity, ft./sec.
g = gravitational constant, 32 ft./(sec.) (sec.)
k = specific heat ratio, C_p/C_v
R = gas constant
M = average molecular weight of exhaust products
T_c = combustion temperatures, ° K.
Pc = chamber pressure, lb./sq.in.abs.
Pe = exhaust pressure, lb./sq.in.abs.
Isp = specific impulse, sec., $= F/W$

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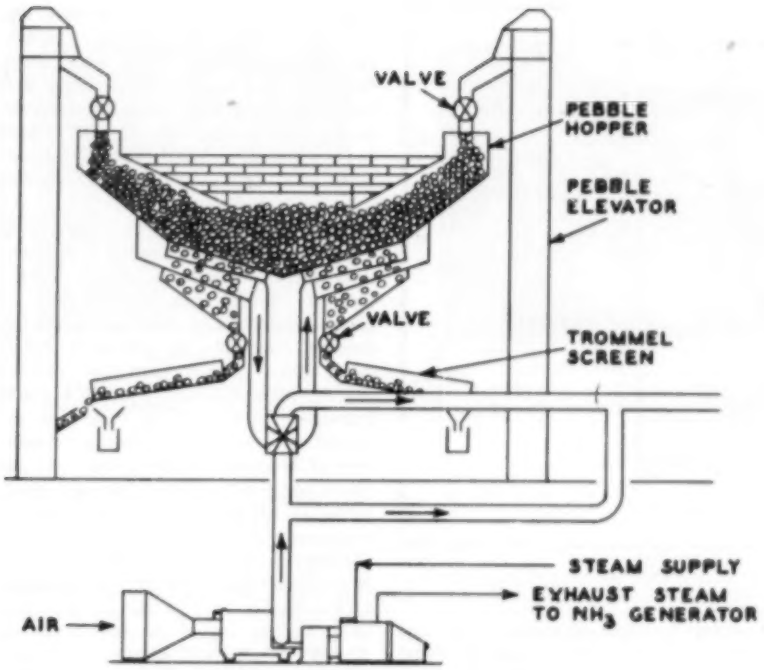

WISCONSIN PROCESS

PEBBLE FURNACE

FIXES ATMOSPHERIC NITROGEN

E. D. Ermenc | Food Machinery and Chemical Corporation, New York

The reaction for the formation of nitric oxide from air has been the subject of extensive study since the days of the now-obsolete electric-arc furnaces. A new thermal process, known as the Wisconsin Process, has been developed and operated on a semicommercial basis. Its furnace provides temperatures in the region of 4000° F. with natural gas or fuel oil. Reaction is rapid at these high temperatures, but a high quench rate is imperative to capture a major portion of nitric oxide formed. Results from the first semicommercial operation are described.

History

The original work on high temperature fixation of nitrogen via the Wisconsin Process was started in 1939 at the University of Wisconsin, Madison, at the suggestion of Frederick Cottrell. At that time Cottrell, who was working with his associate, Percy Royster, on pebble heat exchangers, saw the possibilities for heating air to temperatures necessary for fixation of nitrogen and providing a rapid chilling rate to prevent decomposition of the nitric oxide formed.

By 1942 Cottrell's principle had been proven although the type of furnace used provided for only a few hours operation before becoming inoperative owing to shrinking and cracking of the refractories. Further experimenting with various refractories to withstand the high temperature resulted in 1942 in the basic Cottrell patent (*1*), which was assigned to the Wisconsin Alumni Research Foundation. The latter then provided the necessary financial aid to continue the studies.

Subsequent work established that 97% MgO has the ability to withstand the high temperatures of a nitrogen fixation furnace, and later a successful furnace was built and operated for a short time. By 1946 the basic principles of the process had been demonstrated although all problems had not been solved. At that time Food Machinery and Chemical Corporation became interested and entered into a license agreement under which it had the responsibility of commercially developing the process with the Foundation assisting in this work.

Food Machinery Corporation, which later became The Food Machinery and Chemical Corporation, built and operated a number of unsuccessful pilot scale furnaces based on the fixed-bed principle used at the University of Wisconsin. Figure 1 illustrates a cross section of an early fixed-bed furnace. Such furnaces were unsuccessful for sustained operation due to the sintering and plugging problems inherent in the system. Utilization of the moving-bed principle eliminated the sintering and plugging problems. Satisfactory nitric oxide yields were obtained in the pilot plant, and the suspended arch roof furnace served for a year at temperatures above 3800° F. The roof was considered good for several more years. Figure 2 shows a plan of the successful

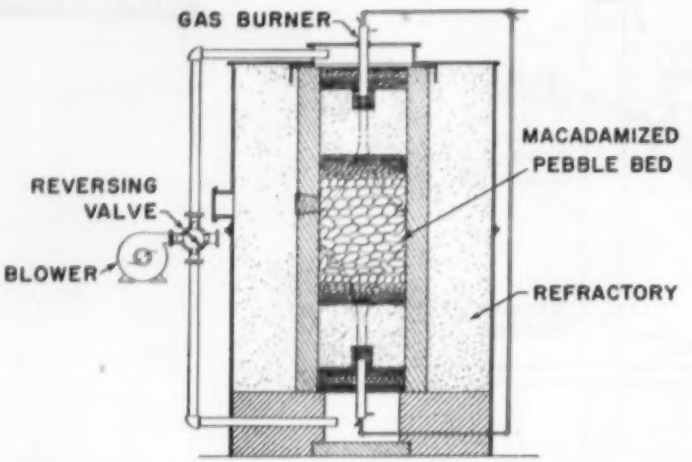

Fig. 1. Early pilot furnace.

pilot furnace which served as the basis for the larger furnace design.

The U. S. Government became interested in the process, and a demonstration plant, designed to produce 40 tons/day of equivalent 100% HNO_3, was constructed at Sunflower Ordnance Works near Lawrence, Kansas. This project, completed in April, 1953, was financed by Food Machinery and the Ordnance Corps of the U. S. Army and operated by Food Machinery's Westvaco Chemical Division.

The plant was operated until October, 1954, when it was shut down since all important data had been obtained. This paper is concerned with the furnace section of the process as operated at Sunflower.

Kinetics

The reaction of nitrogen and oxygen at high temperatures is a relatively simple one when compared with the cracking of hydrocarbons with the numerous side reactions involved. From a practical standpoint the reaction $N_2 + O_2 = 2NO$ is straightforward although from a theoretical standpoint the mechanism may be in some doubt.

The reaction is reversible and requires high temperature to form adequate quantities of nitric oxide. Equilibrium constants were extrapolated from National Bureau of Standards data (*5*). The reaction is endothermic, requiring 38,800 B.t.u./lb. mole of nitric oxide.

Kinetically the reaction can be characterized by the usual second-order rate equations:

$$\frac{dp_{NO}}{dt} = k_1 p_{N_2} p_{O_2} - k_2 (p_{NO})^2 \quad (1)$$

forward

$$-\frac{dp_{NO}}{dt} = k_2 (p_{NO})^2 - k_1 p_{N_2} P_{O_2} \quad (2)$$

reverse

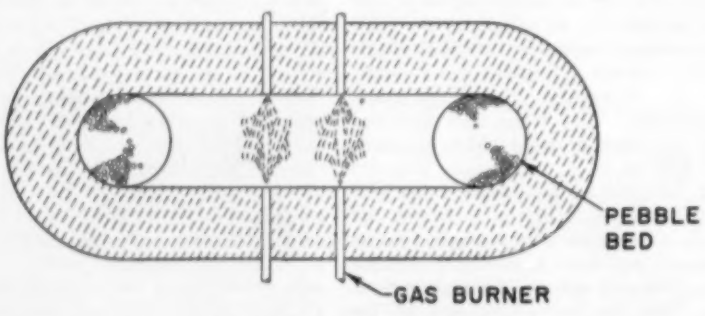

Fig. 2. Final pilot furnace plan.

The forward reaction rate constant, k_1, and the reverse reaction rate constant, k_2, were developed from pilot plant data (*3*) and are shown in Figures 3 and 4. Calculations, based on the data from actual operation at Sunflower, showed that the second-order rate equations were sufficiently good to predict the nitric oxide values.

Since sufficient time is available in the furnace to reach equilibrium, attention is mainly focused on the decomposition of nitric oxide. The rate of decomposition, as characterized by the reverse reaction rate constant, k_2, is many times greater than the forward reaction rate constant, k_1. As a result extremely rapid chilling rates are required to prevent the total decomposition of the nitric oxide formed. If the nitric oxide were allowed to cool gradually, all the nitric oxide would be decomposed. A rapid chill to 3200° F. is required since the rate of decomposition is imperceptible below that temperature.

The pebble beds in the furnace provide chilling rates of the order of 30,000° F./sec., which rate captures a major portion of the nitric oxide. The equilibrium nitric oxide value in the Sunflower furnace was calculated to be approximately 2.5%, the resulting product gas, after chilling, containing 1.8 to 1.9% nitric oxide. Thus, approximately 25 to 30% of the originally formed nitric oxide decomposed even with the rapid chilling rates attained.

Some attempts were made to determine the reaction rate constants and equilibrium constants on the Sunflower furnace. Sample ports, placed flush with the refractory wall, were originally installed for this work, but poor sampling resulted. It was deemed necessary to construct a sample port which could be inserted some distance into the area over the pebble beds, but little time was available to construct a sampler tube able to withstand 4000° F. even for a short period of time. However, as noted previously, calculations of yield based on pilot-plant-determined constants checked out very well. A curve of actual yields from the semicommercial unit vs. wall temperature is shown in Figure 5. The design yield was calculated to be 1.9% at 4000° F., which yield was closely approached.

Process and Equipment Description

The furnace shown in Figure 6 was designed for a nominal production rate of 40 tons/day of equivalent 100% HNO_3, which required 22,000 std. cu. ft./min. of air.

The air is blown into the furnace through one pebble bed and preheated to approximately 4000°F. In passing through the combustion zone, raw natural gas is

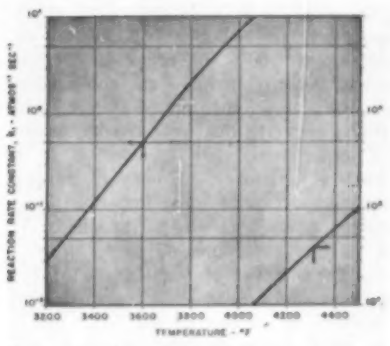

Fig. 3. Reaction rate constant versus temperature for reaction $N_2 + O_2 \rightleftharpoons 2NO$

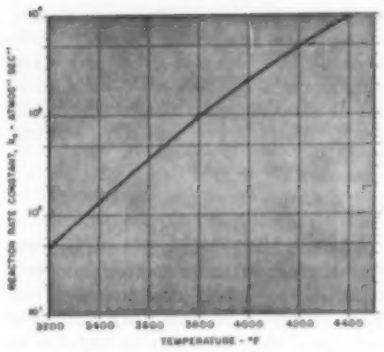

Fig. 4. Reaction rate constant versus temperature for reaction $2NO \rightleftharpoons N_2 + O_2$

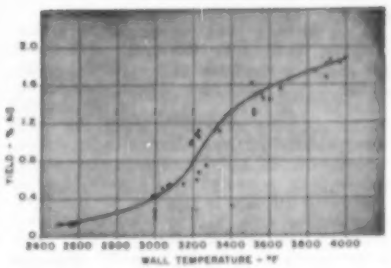

Fig. 5. Actual nitric oxide yield versus wall temperature from 40-ton/day equivalent 100% nitric acid furnace.

introduced to provide the necessary heat for the formation of nitric oxide and to compensate for heat losses. Calculated gas temperature is of the order of 4300°F. based on the measured wall temperature of 4000°F. Approximately 2.5% nitric oxide is formed, and the gases pass downwardly through the second pebble bed acting as the chilling bed. At the same time heat is stored in the bed for preheating air in the second half of the cycle. Rapid chilling is accomplished which results in an effluent gas containing 1.8 to 1.9% nitric oxide. Reversal occurs when the exit gas reaches a temperature of 550 to 600°F. The time for one-half cycle is 3 min. Upon reversal of the 4-way valves, the former chilling bed becomes the preheat bed and the preheat bed acts as the new chilling bed.

Furnace pebbles are circulated at a rate of 500 to 2000 lb./hr. controlled by means of a reciprocating grate mechanism. Pebbles are automatically removed from the bottom hopper through a pressure seal of valves, screened, elevated to the top of the furnace, and recharged into the furnace storage bin through another pressure seal of valves. Sufficient pebble inventory is maintained to provide a seal against the hot gases. The blower used was a positive displacement unit manufactured by the Read Standard Corporation and powered by a noncondensing steam turbine. The pressure drop through the furnace was 4-5 lb./sq. in.

To provide for the reversals of flow, three 4-way, 12-in. diam. plug valves, made by American Car and Foundry, were installed in parallel and connected by a common linkage. Three valves were used since larger valves were not obtainable. Power was provided by a hydraulic cylinder, which was actuated by the temperature of the effluent gas from the furnace. To prevent any appreciable pressure build-up,

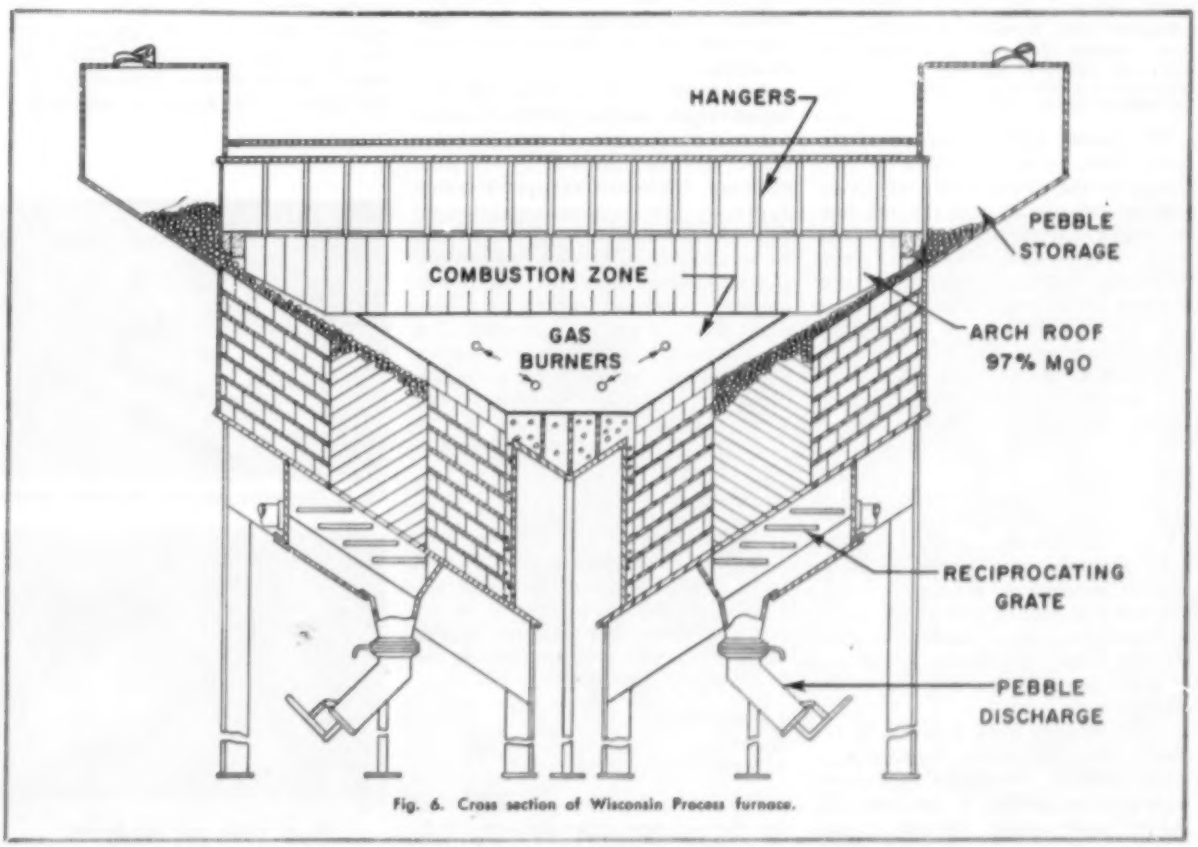

Fig. 6. Cross section of Wisconsin Process furnace.

the reversals were required to be quite rapid and were accomplished in 0.5 sec. Blower discharge pressure rise on reversal amounted to 3 lb./sq. in. due to the fractional part of a second the valves were closed.

The furnace was a special structure weighing more than 400 tons, constructed for pressure operation of 8 to 10 lb./sq. in. gauge. The approximate outside dimensions were 54 ft. × 21 ft. × 20 ft. The refractories in the hot zone were 97% MgO, the walls being about 4 ft. thick. The refractory roof, which covered both combustion zone and pebble beds, consisted of a suspended arch. Figure 7 reveals a portion of the arch roof and a view of the combustion zone showing two burner openings. The brick were standard 15-in. high purity magnesia set against spring-adjusted skewback brick. The brick were suspended by type 309 stainless steel hangers set in the brick notches. The hangers in turn were supported by type 304 stainless steel rods hung to the steel arched roof. In order to prevent by-passing of air between the roof brick and steel roof, Inconel baffles were installed at three points, and nickel sheet was placed between roof brick faces (2). Water cooling of the steel roof was provided.

The pebble bed dimensions were 10 × 12 × 4 ft. deep. Pebbles averaged ½ in. in diam. and were also of 97% MgO. Figure 8 shows a view of the pebble beds pointing toward the pebble feed chute. Due to the large surface area of the pebbles a high heat transfer rate was achieved between pebbles and the air stream. Actual values of the heat transfer coefficient ranged from 1.0 to 1.5 B.t.u./(sec).(°F.)(cu.ft.) At such rates of heat transfer 22,000 std. cu. ft./min. of air could be preheated from 200 to 4000°F. in the 4 ft. of bed depth available. To prevent by-passing of gas through the refractory walls, Inconel and nickel sheets were installed between each course of brick and welded to the steel shell. Water cooling of the shell was provided to protect the sealing sheets (4).

The normal angle of repose of the ¼-in. diam. spherical pebbles is 33°. Owing to the lifting action of air in passing upwardly through the bed, flatter angles of repose occur up to the point of 0° angle of repose where fluidization begins. The furnace was designed for a superficial velocity of 200 std. ft./min. which corresponds to an angle of repose of 20° at operating temperature. Feed pebbles thus could flow by gravity into the pebble-bed zone during operation. The pebbles served as a seal against hot gases reaching the steel structure.

The time available in the combustion zone was 0.5 sec., whereas less than 0.1 sec. was necessary to reach equilibrium. Structural requirements for placement of burners and necessary fuel mixing and combustion time requirements increased the size of combustion zone. Chilling time approximated 0.02 sec. to reach the 3200° F. temperature required.

Eight burners were provided in the combustion zone, which burners were water jacketed. The tips of the burners were exposed to 4000° F. but were adequately water cooled. Material of construction was 304 stainless steel. Natural gas was supplied at 100 lb./sq. in. gauge.

The grates supporting the pebble beds were of 304 stainless steel and were installed at a 20° angle with the horizontal to provide a uniform pebble-bed depth. Each grate assembly weighed 10 tons.

Controls

The reversal or cycling of the process gas was automatically controlled by two electronic recording potentiometers, one controller for each bed. Each controller had three thermocouples in parallel in the exit ducts, and the electrical circuits were such that any one of the three thermocouples would operate the controller. Either one of the controllers was able to function for both pebble beds in case of malfunction of one controller and also to allow servicing.

Alarms were interlocked into the circuits such that if the gas temperature rose 50° F. beyond the set point, due to failure to reverse, an alarm was actuated. If the temperature continued to rise 50° F. more, another interlock shut down the main blower and closed the fuel gas valve. To provide emergency power, a diesel motor-generator set was available.

Temperature in the combustion zone was checked hourly with an optical pyrometer, and fuel gas input was manually controlled on the basis of these readings.

A multipoint timer controlled the valves which allowed pebbles to enter and exit the furnace. A multiple-valve system was used, operated by hydraulic cylinders. Cycle time was approximately 5 min.

Condensate grade water was utilized for the cooling of furnace elements exposed to high temperature and it was extremely important to have water flow at all times to prevent burn-outs. The condensate cooling system was captive, and a pressure switch on the pump discharge provided for diversion of city water from an elevated water tank in case of low pressure or pump failure.

Operation Notes

During operational periods little downtime was experienced. However, faults in original design were apparent, of which some were corrected on the spot and others on subsequent installations. The major points of trouble can be summarized as follows:

1. combustion
2. pebbles
3. grates

The combustion zone or open part of the furnace was approximately 35 ft. long by 12 ft. wide and averaging approximately 4 ft. in height. Fuel usage amounted to 14,000,000 B.t.u./ton of equivalent 100% nitric acid. Design actual velocity through the combustion zone was approximately 50 ft./sec., and it was expected that little trouble would be experienced with combustion in a 4000° F. chamber. However, mixing time proved to be quite important, and design throughput was not attained. At a velocity of around 40 to 45 ft./sec., the flame licked at the surface of the pebbles resulting in some reduction and deposits of carbon in the bed. Yields of nitric oxide dropped owing to the reducing action of carbon. The only remedy at the time was to reduce air flow below the critical point. Either one or several of the various corrective possibilities, including the following, would likely be successful for the future:

1. redesign burners to reduce flame length.
2. increase length or area of combustion zone.
3. relocate burners to obtain maximum use of combustion zone.

Screening of pebbles was performed by a trommel-type screen, which later proved to be inadequate. An emergency shutdown was experienced after about five months of operation which was heralded by extremely rapid reversals of approximately 10-sec. duration. The rapid reversals indicated by-passing of the pebble beds resulting in little heat pick-up by the pebbles. Upon entry into the furnace, after a suitable cooling pe-

Fig. 7. Combustion zone with two burner openings.

Fig. 8. Pebble entry into furnace.

riod, large agglomerated chunks composed of chips and fines were found in the bed. The collapse of a large chunk had provided a channel for the hot gases to pass through, and damage to the grates was apparent. Fines and chips were noted also in the feed entry chute indicating rather poor screening, and which fines and chips provided excellent material for sintering and agglomerating. Better pebbles were an obvious requirement, but it appeared that with proper screening the formation of large agglomerates could be eliminated. Tests on the trommel showed only about a 30% efficiency in getting rid of fines and chips. As a result a second screen was installed at the bucket elevator discharge, the trommel being located at the bucket elevator inlet. Average pebble breakage at 4000° F. approximated 5% of the circulation rate, but at 3700° F. the breakage is expected to fall to 3% with lower rates possible with improved pebbles.

The grates were damaged by the high temperature to which they were subjected, and the units had to be removed and straightened. The main beams and other critical members were water cooled after reinstallation not only because of the damage caused by the by-passing of the pebble beds, but because of higher than design temperatures experienced during normal operation. Expected grate temperatures were of the order of 1000 to 1100° F., whereas 1200 to 1300° F. temperatures were experienced. Temporary measures with air cooling had been provided before the shutdown to prevent overheating.

After alterations had been made, the unit was started up again and ran for approximately two months when pebble breakage and pressure drop across the beds began to increase. After another month, with no success in the reduction of the pressure drop, the furnace was again shut down. Entry into the furnace again showed large agglomerated lumps which, however, could be broken by a hand blow. Agglomerates from the first shutdown could be broken only with a pickaxe.

It was apparent that operation at 4000° F. was hardly possible at the present stage of pebble development. Data at 3700° F. wall temperature indicated that pebbles would stand up under those conditions although production would be lowered.

The refractories of 97% MgO performed well in the furnace. Some minor slumping was noted but nothing appreciable. The refractory roof was considered the critical component of the furnace due to the long span of 18 ft. However, except for some initial spalling which occurred before the furnace got up to temperatures, and after a crash shutdown caused by failure of the main blower, the roof was satisfactory. Figure 9 is a photograph of a roof section showing spalling. The original spalls varied in thickness from ½ to 2 in. and were designated as primary spalls. No secondary spalls were ever observed in the one year of operation subsequent to the blower failure. The roof life was estimated to be four to five years based on examination after the last shutdown.

Figure 10 is a view of the furnace exterior during construction and Figure 11 shows the arch roof construction at the pebble feed end.

Notation

p_{NO} = partial pressure of nitric oxide
p_{N_2} = partial pressure of nitrogen
p_{O_2} = partial pressure of oxygen
k_1 = forward reaction rate constant
k_2 = reverse reaction rate constant
t = time

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Fig. 9. Furnace roof showing primary spalls.

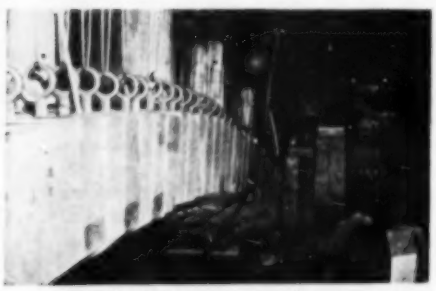

Fig. 11. Refractory arch roof construction at pebble feed end.

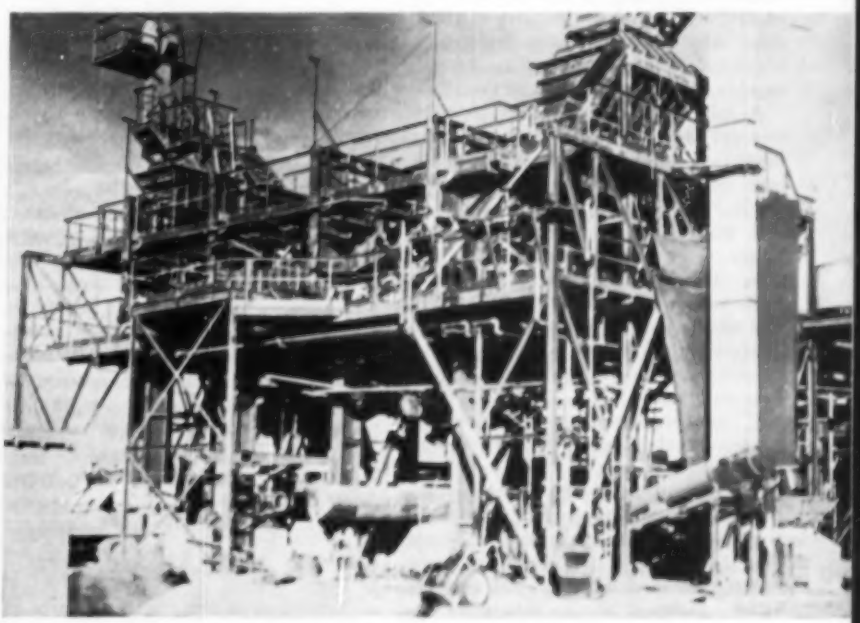

Fig. 10. Furnace exterior during construction.

THE CHEMICAL ENGINEERS' NUCLEAR FUTURE

Nuclear science is still in its infancy. Nuclear engineers can proceed to make this new tool valuable to mankind only as rapidly as chemical engineers can explain how to handle the problems of high temperature, heat transfer, corrosion, and materials.

C. Rogers McCollough | Monsanto Chemical Company, St. Louis, Missouri

To predict the direction of growth of atomic energy in its present state of infancy remains difficult. However, one thing seems certain—chemical engineering will play a significant role in making practical many applications of this science. It is the purpose of this article to indicate what some of the likely avenues of development will be, and how the ingenuity of many different specialists, including the chemical engineers, will be required to bring about their practical realization.

One hears a good deal about nuclear engineering and the nuclear engineer. It would be helpful to define the latter as one who takes the scientific facts of nuclear reactions and designs, builds, and operates machines which produce energy or materials generally useful. Very often, chemical engineers serve as nuclear engineers, as do engineers from other branches of the profession. That a chemical engineer makes a special kind of nuclear engineer will be brought out in this article for the purpose of clarifying what must sometimes seem to be a confusing situation, that is, *who* is capable of doing *what* around the atom.

A brief review of presently existing reactors and the problems attending them may serve to provide a take-off base for the future possibilities and needs.

A general problem common to all reactors is the formation of fission products. These are extremely toxic materials and positive assurance that they will not escape is one of the important and difficult problems in designing and locating nuclear reactors of any significant power.

Heterogeneous reactors require pure uranium which needs the devising of chemical engineering processes and equipment for producing uranium compounds of exceedingly high purity so that metallurgists can convert these materials into suitable plates and rods. Military reactors with enriched uranium call for gaseous diffusion separation, the existing plants for which are, indeed, an outstanding example of American chemical engineering. Production of high purity graphite, of heavy water, of even ordinary water of extremely high purity, and of neutral pH has been effected through the contributions of chemical engineers.

In the interest of neutron economy, the chemical engineer's universal cure-all—stainless steel—could not be used in the core of thermal reactors, and the present operating power reactor in the "Nautilus" would not have been possible if the chemical engineers had not devised processes for producing pure zirconium metal, free of hafnium.

Homogeneous reactors are essentially simple in concept. This type of reactor, however, turns out to be a plumber's nightmare. Among other problems, a way must be found to control the composition of the reacting solution ("soup"), which means not only control over uranium concentration, but also over pH and various anions to be sure that the uranium stays in solution. The main difficulties with homogeneous reactors arise, however, from the fact that they must be operated at high pressures and temperatures, a condition which results in severe corrosion, affects the stability of the "soup" especially under radiation, and imposes problems on the chemical processing plant.

Fast reactors operating with neutrons which have not yet been slowed down offer much wider leeway in the selection of materials. At present all fast reactors are heterogeneous, and coolants are sodium or other liquid metals because the introduction of compounds having atoms of low atomic weight, like hydrogen, carbon, or oxygen would result in appreciable degradation of neutron energy. The intense, high energy neutron flux tends to break down chemical compounds, hence one must rely, apparently, on such elemental substances as liquid sodium. Corrosion of the fuel elements and of the structural parts of the reactor by the circulating liquid metal presents a serious problem as does the problem of preventing reaction betwen hot liquid sodium and water. There has been much study, experimental work, and expensive constructions to assure that this latter possibility does not happen, but it is the author's view that the problem is not yet satisfactorily solved. In designing heat exchangers for this purpose, one must cope with new problems of stress corrosion.

The relation between the chemical composition of the liquid metal and stress is a new problem requiring careful study. Experimental work is also undoubtedly required before reliable and economical heat exchangers are obtainable for this use.

If one is dealing with heterogeneous reactors, the solid fuel elements will require, in most cases, chemical processing before a large fraction of its contained fissionable material is used up. This condition is due to the need for preserving enough fissionable material in the core for a critical mass. Usually, fission products are overshadowed by so-called "radiation damage," the battering given fuel material by fast neutrons and recoiling fission fragments. This damage causes the fuel elements to grow anisotropically—they swell, twist, or warp. They may become brittle, and the cladding may crack. In other words, they are so badly damaged that one does not dare leave them in the reactor.

Such fuel elements are removed from the reactor, dissolved, and put through an extensive chemical processing to separate the fission products from the unused uranium. If any plutonium has been generated, this must be separated also.

Although the fuel cleanup process (C.E.P., October, 1955, page 446) may seem relatively simple in theory, it is expensive because of the great radioactivity of the fission products and this is another major handicap to the nuclear power program. This means that fuel elements must be allowed to "cool" more than a month in order to get the radioactivity down to a level where it will not heat solutions excessively or break down the organic solvent and chelating agent. The whole process must be carried out by remote control and behind thick concrete barriers. Any maintenance of equipment must be done either by remotely operated cranes, wrenches, and other tools or after expensive, time-consuming decontamination. Waste storage is a laborious, expensive operation. It is easy to see that with respect to *present* reactors, the chemical engineer's ingenuity and specialized training will continue to be regarded as primary in achieving economic as well as technically sound atomic power generating plants. Now to turn to what lies

ahead, to some of the regions which may be far more revolutionary as far as their effect on chemical processing is concerned.

Higher Temperature Limits

The fission process has certain unique features which have not been fully exploited as yet.

In the first place, the reaction is not temperature limited. Temperatures as high as millions of degrees centigrade are possible and temperatures of thousands of degrees centrigrade are easy to get. In reactor design, one makes sure that these temperatures are not reached accidentally. In the second place, the reaction is self-contained. There is no need to bring in air and fuel or to take away flue gases and ashes in order to carry on the reaction and generate the heat. In the third place, the whole reaction is in a highly radioactive environment.

Up to now, most operating reactors have maximum, useful temperatures up to about 600° F. This rather modest temperature limit is because, as yet, the engineers have not been able to develop systems to go any higher. This is a limitation due to materials, corrosion, and stresses. The role of the chemical engineer is apparent in this problem.

In the foreseeable future it appears possible to raise this temperature several hundred degrees, a relatively modest increase. The modesty is due to the lack of suitable materials and techniques to go higher. The point should be stressed that the design of a nuclear reactor operating even at room temperature is a hard job. Designing it to operate at 600° F. is much harder and to go to 1000 or 1400° F. is really difficult.

Water, whether light or heavy, is an excellent material for heat removal. For thermal reactors it has the advantage of acting simultaneously as a moderator and coolant. Much is known about handling water, although amusingly enough, it turns out that there are some rather important gaps in the knowledge which are being filled by the necessities of the science and technology of reactors. Water, however, has the drawback that its boiling point is only 212° F. When the desire is to go to high enough temperatures to generate power, high pressures are required with the attendant expense and difficulty of high pressure construction.

Hydrocarbons can be found with considerably higher boiling points and they, too, have desirable moderating properties. The difficulty is finding hydrocarbons with the desired physical properties which will withstand the desired temperatures and the bombardment in the radiation field within a reactor. It appears that some compounds may have sufficiently low decomposition to make them feasible for this purpose. Hydrocarbons have another advantage in that they do not have the thermodynamic possibility of strongly exothermic reaction with metals such as aluminum, zirconium, or uranium. This possibility of hot fuel elements containing aluminum, zirconium, or uranium reacting violently with water significantly raises the hazard problems of nuclear reactors. If one uses hydrocarbons as reactor coolants and moderators, inevitably there will be a certain amount of decomposition and it will probably be necessary to install a chemical process to purify continually the material as it is circulated through the reactor system.

The design of still higher temperature reactors up to 3000 and 4000° F. is the real need for more adequate use of this new tool. With these temperatures one can begin to consider metallurgical processing, reduction of metals, manufacture of fuels, and perhaps the synthesis of basic chemical raw materials such as nitric oxide, acetylene, and cyanogen.

Nucleometallurgy

Today, when high energy processes like the manufacture of chlorine, sodium, magnesium, aluminum, graphite, and phosphorus are to be carried out, electricity is used. However, electricity is nothing but energy with a very high temperature potential. In making electricity from a chemical process like burning coal one takes rather high energy losses, about 60% at the least in the most modern plants, but actually more like 75% on the average. Moreover, there is a lot of equipment, that is to say *capital*, tied up in the plant that makes the electricity.

The advent of nuclear energy gives another source of high temperature energy for the manufacture of basic chemical raw materials if one can but find the way to use it.

If a plan calls for building nuclear chemical plants, the question is what role chemical engineers will play in the design and operation. There is relatively little difference in the nuclear reaction characteristics up to, say, 1000° F. When temperatures of 3000 and 4000° F. are reached, there are some differences and the nuclear engineer will have to do his part in designing a stable reactor. The mechanical engineer will have the difficult job of designing for tightness and containment allowing for expansions and the development of thermal stresses. The really tough part of the job falls on the shoulders of the chemical engineer. He must find materials that will stand the temperature and the corrosion, and will have to devise the heat transfer system. Incidentally, up to now reference is frequently made to the problem of "cooling reactors" rather than *using* the *heat* of reactors. Again, the chemical engineer will have to devise the flow system and to design the auxiliary systems that bring in the raw materials and take out the finished chemical products.

If materials pass through a neutron flux, a certain amount of activation or transmutation takes place. This invariably makes certain of the materials radioactive. There will be the problem of separating these radioactive materials from the main products, and a process must be designed to do it.

Nuclear Aluminum Plant

Simply to illustrate—and illustrate only—a nuclear chemical plant, one can imagine a plant to produce metallic aluminum. It may not work; the thermodynamics have not been checked. There are serious doubts about the economics since electricity is quite cheap and its use to produce aluminum is well understood. But anyway, the design of a nuclear reactor to produce aluminum is the immediate proposition.

In any event the supposition is that aluminum oxide and carbon will react in a nuclear reactor as follows:

$$Al_2O_3 + 3C \rightarrow 2Al + 3CO$$

and it has been determined that this reaction will go rapidly at 4000° F. at atmospheric pressure.

The first step is for the nuclear engineer to figure out what kind of a reactor would produce some amount, say, 1000 tons/day of aluminum by this reaction. Since high temperatures and essentially a reducing atmosphere are being dealt with here, he selects graphite and silicon carbide as the materials of construction. The design will be essentially a cube in which graphite will be arranged to give a series of vertical rectangular passages. These will be lined with silicon carbide strips which are the fuel elements and will be made by pressing a mixture of uranium carbide and silicon carbide together under high pressure and sintering to form long strips. They then will be coated on four sides and on the ends with sintered silicon carbide. This sealing or "canning" the uranium inside silicon carbide is so that fission products cannot escape and contaminate the product. Briquets of aluminum oxide and carbon will pass down the slots. Carbon monoxide will come off the top and molten aluminum out the bottom. The nuclear engineer will specify the ratios of graphite, aluminum oxide, carbon, silicon carbide, uranium, and voids that can be used. He will also calculate the

amount of uranium required and its concentration of U^{235} enrichment, as it is called.

Certain impurities are bad neutron absorbers, others become highly radioactive. The chemical engineer, therefore, will have to devise processes to make aluminum oxide and carbon which are *free* of these impurities, otherwise the reactor would not run or the product would be so radioactive it never could be used. The process of melting and briquetting the alumina and carbon is again the chemical engineer's job. The preparation of suitable silicon carbide and the making up of the fuel elements are chemical engineering concerns. Other jobs for the chemical engineer are the heat transfer problem in the reactor and the treatment and disposal of the carbon monoxide off-gas. Dissolving and separating fissionable material from fission products in the spent fuel elements is certainly a part of the chemical engineer's assignment.

Skill Requirements

Whether these nuclear chemical plants become a reality or not depends on chemical engineers solving the problems of design. If such problems do appear on the scene, it is obvious that the operation of so valuable and intricate a plant would not be trusted to anyone except a chemical engineer.

The new science of nuclear energy and its application should properly be guided primarily by those skilled in nuclear energy. It is clear, however, that progress in nuclear reactors has been largely dependent upon the valuable contribution made by chemical engineers in the preparation of reactor materials, in the design of the cooling system, and in the chemical processing of the used fuel elements. The major problems presently holding back progress in nuclear reactors—the design and fabrication of fuel elements, the cost of chemical processing, and the disposal of fission products at reasonable costs—are certainly fields in which chemical engineers should make important contributions.

As science finds uses for fission products, it is up to chemical engineers to use their skills and imagination to find means of handling them economically. Finally, if it is expected that the real potentialities of nuclear energy in the future will be utilized, chemical engineers must show how this high potential energy source can be handled *economically* and *safely* so that it can be used for the reduction of metals, for the manufacture of fuels, or for the preparation of basic chemical raw materials.

Presented at A.I.Ch.E. meeting, Lake Placid, New York.

What's in

Symposium Series Volume 50

(Series 15—"Mineral Engineering Techniques")

Introduction to Flotation

E. H. Crabtree

Flotation may be defined as a method of concentration in which one or more of the mineral constituents are collected by causing them to float above the surface of a pulp consisting of the finely pulverized ore and water. Probably no metallurgical process in the history of the mining industry has been responsible for such increased mineral production as has flotation. It is commonly practiced in an ore pulp in which the ore has been ground to a maximum of some 35 mesh, but fine enough to effect considerable liberation of the mineral components. This process as presently practiced is termed froth flotation. Several early processes were generally classed as skin flotation or film suspension. It has been said that flotation is an art instead of a science. Review of the literature discloses that hundreds of investigators have worked continuously since the process was discovered to attempt to change this statement. Much has been learned.

Chemical Engineering Progress Symposium Series No. 15, Vol. 50, 1 (1954).

The Chemical Theory of Flotation

P. L. de Bruyn

Flotation is recognized today as one of the most important methods for concentrating low-grade ores. At present the physical-chemical processes which determine the flotation behavior of minerals are not completely understood; however even though it is not possible to formulate a complete quantitative explanation of the flotation process, many of the important chemical factors which control the floatability of solids have been recognized and evaluated at least semiquantitatively. Flotation research is progressing actively.

Chemical Engineering Progress Symposium Series No. 15, Vol. 50, 5 (1954).

Froth Flotation of Chalcopyrite

Arvid E. Anderson

A brief description of the flotation operations as practiced in the recovery of chalcopyrite has been presented. The present plant practice has resulted in an unusual accomplishment regarding the recovery of the chalcopyrite. The amount of copper in the ore has decreased; yet the recoveries have been maintained without serious reduction in the averaged grade of concentrate produced. This achievement is believed to be due to two operating factors: namely, first, the use of the dual promoter system, Aerofloat and xanthate, and, second, the flexibility of the operations of the flotation machines, both mechanical and air machines being used in the same circuit.

Chemical Engineering Progress Symposium Series No. 15, Vol. 50, 15 (1954).

Adsorption in the Mineral Industries

C. L. Mantell

Although adsorption is a function of surface forces, in chemical engineering applications the relative amount of adsorbate per unit of weight or volume of adsorbent is large. Commercial adsorbents for the process industries are extremely porous solid foams with large internal surfaces, their external surface comprising only a small part of the total surface. The adsorbed atoms or molecules may be bound to the surface of the solid in different ways: there may be a weak interaction between solid and gas, similar to condensation, or a strong interaction, similar to chemical reaction. The former is called physical and the latter, termed chemisorption, is also known as activated adsorption, which implies that this type of adsorption requires activation energies just as do chemical reactions. The chemical engineer accepts adsorption on extended surfaces of ions, compounds, molecules, and gases and has developed processes for collection, separation, and fractionation involving adsorption and desorption, largely as functions of physical factors as well as chemical factors such as *p*H.

Chemical Engineering Progress Symposium Series No. 15, Vol. 50, 21 (1954).

Hydroseparation and Thickening

W. P. Dyrenforth

The field for the hydroseparator may broadly be divided into three classes:

1. For fine separations where large areas and very quiescent conditions are essential.
2. For rough sloughing off of slimes ahead of additional treatment.
3. For rough removal of fines and dewatering of a dilute and large volume feed.

It is sufficient to say that the principles of hydroseparation and of sedimentation-type thickening and the means for applying them have wide use in industry whether the process is chemical or metallurgical.

Chemical Engineering Progress Symposium Series No. 15, Vol. 50, 65 (1954).

(To be continued)

Freeze seals have been developed for sealing stationary and rotating shafts affording a simple means of adapting commercial equipment for use in high-temperature liquid-metal systems. Several designs for sealing sodium at temperatures up to 1200° F. have been satisfactorily tested. Under different operating conditions cooling loads, torque, and temperature distribution were measured. Locating the freeze seal away from the high-temperature region allows the formation of an annulus of frozen metal around the shaft with small cooling loads.

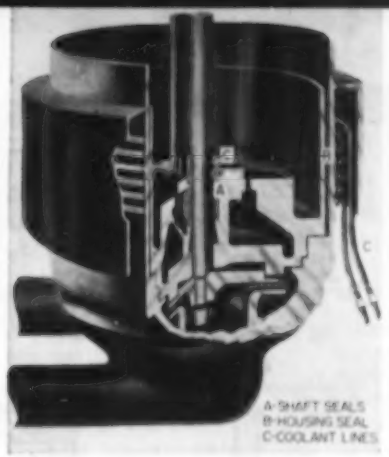

Fig. 1. Pump modifications for freeze seals.

design and operation of

FREEZE-SEAL VALVES AND PUMPS

R. Cygan and A. M. Stelle

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Canoga Park, California.**

Broader application of high-temperature, liquid-metal heat transfer systems is possible by reducing component costs. Use of freeze seals in valves and pumps affords a method of reaching this goal. In addition, design simplification together with operating ease often are concomitant gains.

The necessity for other than standard designs is dictated by the corrosive action of liquid metals on packing materials having adequate tightness and/or temperature suitability. The freeze seal avoids these difficulties and offers simple arrangements for sealing shafts that are adaptable to either static or rotating seals. The operating principle is to form a barrier between the system and the outside by freezing a slug of the process liquid metal in a narrow passage. The frozen metal is held in the narrow passage, which is usually an annulus, by friction and adhesion. Complete containment, i.e., prevention of extrusion, is not always a requirement, but experience indicates that it can be achieved.

In a rotating seal, the frozen metal is continuously sheared near the shaft surface and a thin high viscosity liquid film is maintained at the shear interface. Although the exact action is not known, friction energy probably supplies the heat necessary to maintain the liquid film while the high thermal conductivity of the frozen metal permits rapid heat removal so that the film does not become thick enough to allow leakage. The heat from the hot liquid metal and the frictional heat (in the case of rotating shafts) are removed continuously from the frozen area to a secondary coolant which may be either a liquid or a gas. The liquid-cooled seal is the more compact design and is the type discussed here.

Another advantage of the freeze seal is the relative ease with which it can be adapted to commercial equipment.

Valves can be converted by simply adding a new bonnet incorporating cooling passages along the stem. The bonnet is welded to the body since corrosion or erosion of the valve seats is nil with sodium, and maintenance therefore is not necessary. Compact designs are possible for use with large-size plug, globe, or gate valves. Globe and plug valves of 6-in. pipe size have been built and successfully tested at Atomics International. Centrifugal pumps require more extensive modifications which usually incorporate two freeze seals, one rotating and one static. The modification for the static housing freeze seal is by far the more extensive.

As shown in Figure 1, extension sleeves are added to the head and case which provide a narrow annulus somewhat removed from the hot liquid-metal region.

A cooling jacket placed around the outer extension sleeve provides the necessary cooling to form the static freeze seal. The gas space behind the freeze seal is closed off from the outside atmosphere by conventional means. This permits introducing inert gas to blanket the exposed frozen metal of the freeze seal. This design permits the bolting for the two parts to be placed in a cool region above the seal. A liquid-cooled gland unit is inserted into the stuffing box to provide the cooling to form the rotating shaft freeze seal. Although a larger diameter stuffing box usually is required for a freeze seal gland than for an ordinary gland packing, most pump castings have adequate metal thickness to permit increasing stuffing-box size without changing the original patterns.

The cooling requirements for these shaft and static freeze seals are not excessive. Since the chief heat paths are through the metal container, shaft, and the liquid metal in the annulus, the cooling load may be approximated by evaluating these lines of heat flow by ordinary conduction heat transfer methods. The additional heat generated in shearing a rotating seal is a minor part of the total cooling load and may be ignored in the first approximations. The shaft power thus absorbed in a rotating seal is independent of the temperature of the frozen metal but is a function of the frozen metal length and the thickness of the liquid film.

It is difficult to predict the shearing power loss and to date there has been little correlation between theoretical calculations and experimental data. Close temperature control of the seal does not appear necessary as long as the temperature of the frozen metal is kept well below its freezing point.

However, the starting torque is generally high (25 ft.-lb. for 3-in. shaft) and apparently a function of the temperature (i.e., shear strength) of the frozen plug. As the plug temperature approaches its melting point, the shear strength and starting torque are reduced, and it appears that the allowable approach to the freezing point is proportional to the thermal conductivity of the metals involved. Thus, a seal with metals of good thermal conductivity permits a closer approach. High pressure differentials across the seal also increase the running torque and further increase the severity of a leak in case of seal coolant failure. Low differentials may be achieved by adjusting the pressure of the inert gas backup to nearly equal the pressure of the liquid metal. The curves in Figure 2 show representative data for sodium freeze seals of various designs.

The pump bearing housing cooling load is shown also for comparison.

Vertical shaft seals present no problem in achieving a solid plug around the entire annulus. However, with hori-

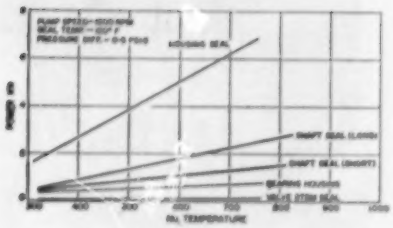


Fig. 2. Cooling load for freeze seals.

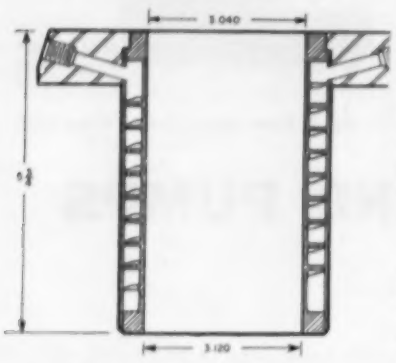


Fig. 3. Long freeze-seal gland.

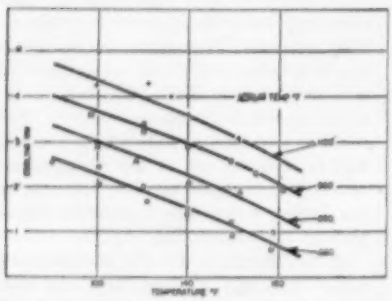


Fig. 4. Long seal cooling load 6- by 8-in. pump.

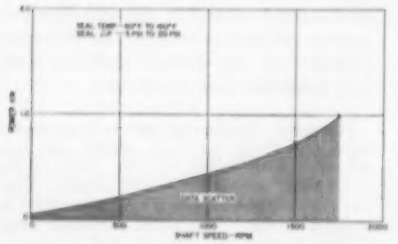


Fig. 5. Shaft power dissipated in long freeze seal 6- by 8-in. pump.

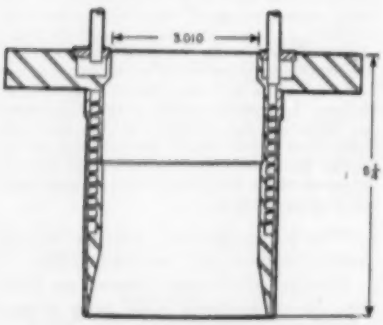


Fig. 6. Short freeze-seal gland.

zontal shafts, some difficulty may be encountered in obtaining a plug free from horizontal cold shuts which may promote gas inleakage if the liquid-metal system drops below the backing gas pressure.

Standard shaft finishes appear to be satisfactory and hard surfacing is unnecessary or perhaps undesirable since spalling and chipping of a type 410 Malcomized stainless steel shaft have been experienced The wobble and vibration of a turning pump shaft must be kept below 0.001 in. total indicator reading to avoid plastic working the frozen metal and thereby encouraging extrusion or excessive frictional heat generation. Because of thermal distortions of pump parts when systems operate at temperatures above 1000° F., the pump shaft deflection due to hydraulic or gravity loads should be kept to less than 0.004 in. to avoid contact and subsequent galling of the shaft and stationary parts.

Contamination of the metal in the frozen seal by abrasive oxides will lead also to binding, seizure, and ultimate mechanical failure. The gas side of the seal, particularly for a system containing easily oxidized materials, must therefore be covered with an inert atmosphere. In addition, the oxygen combined in the liquid metal side (in the case of sodium) must be controlled to a low value since the oxides in alkali liquid metals tend to precipitate in cold regions. For sodium, the oxygen content should be less than 0.005 wt.%.

Operation Test Data

Operating experience with static freeze seals show that those that are operated infrequently present no problem and have proved reliable. Rotating seals appear promising but are not yet fully developed. Two problems to be solved are eliminating thermal stresses and optimizing the configuration for best performance at the lowest cooling load.

A rotating seal annulus with a conical outer surface and cylindrical inner surface to form a tapered slug of metal with radial spacing of 0.020 in. near the gas side and 0.060 in. on the liquid-metal side, operates more smoothly than a straight-sided configuration. The taper apparently provides space and a mechanism by which any lump or abrasive material may be worked out to a larger annular space before seizure or galling occurs. The taper further restrains the frozen plug and assists in preventing extrusion. The freeze-seal gland built to these dimensions for test in a 6 by 8 in. pump is shown in Figure 3.. The seal is fabricated by cutting a double helix for coolant passages in the inner member for the full length of the seal and enclosing the passages with a tubular piece welded at top and bottom to form the outer member. The coolant is circulated from the top to bottom in one helix and from the bottom to top in the other. Some heat is exchanged between the coolant flows but this is of minor concern because of the low-temperature drive. This seal was operated with a 3-in. diam. shaft turning at speeds varying between 45 and 1700 rev./min. Figures 4 and 5 are plots of the experimental data for this configuration.

A modification of this general design uses two independent coolant passages. A cutaway of this design is shown in Figure 6. The lower circuit is fabricated with a double-helix passage similar to the previously described seal. This cooling circuit provides precooling of the liquid metal in a wide annular space which allows any precipitation or accumulation of abrasives to be segregated before it can become entangled in the narrow upper annulus. The upper circuit is a single once-around passage which provides the cooling to freeze the liquid metal in the narrow upper annulus. The upper annulus is short to reduce the axial length of frozen metal and to reduce the thickness of the liquid film formed around the rotating shaft. These conditions minimize the running and starting torque. The narrow upper annulus of this seal has parallel walls of radial spacing of 0.158 in. It is believed that the parallel walls in the upper annulus were responsible for some of the shaft seizure trouble experienced with this seal.

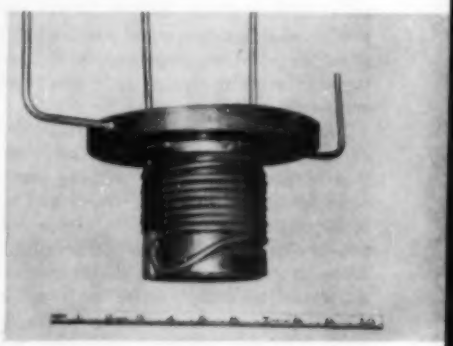


Fig. 7. Short freeze seal with tubular cooling passage.

Both designs have high thermal stresses in the axial direction because of the difference in the average temperature of the inner and outer seal walls. The welds holding the outer enclosure tube at the top and bottom apparently have failed in shear after several thermal cycles causing coolant to leak into the liquid metal. To overcome this difficulty, seals using tubular cooling passages have been fabricated as shown in Figure 7. Each of the previous designs has been thus modified, that is, a seal with one coolant circuit and a tapered annulus and a seal with two independent coolant circuits but also with a taper in the narrow annulus. The tubular sections are completely un-

Fig. 8. Six-inch plug valve with freeze seal.

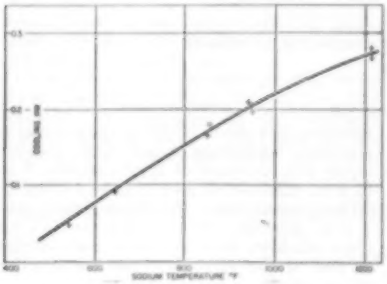
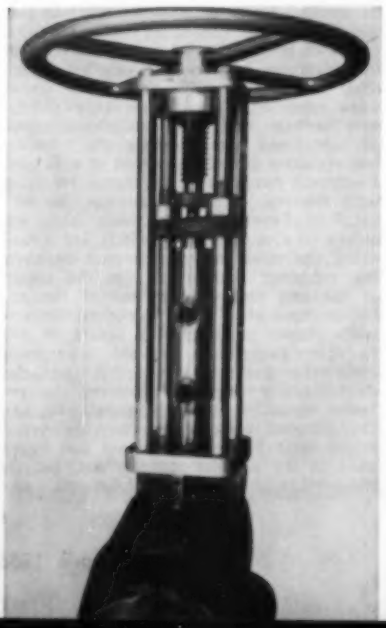


Fig. 10. Seal cooling load 6-in. valve.

Fig. 9. Six-inch angle valve with freeze seal.



restrained. This results in their having maximum flexibility and leaves the seal relatively free of thermal stress; therefore, a shorter cooling section is possible.

Because of the good heat path afforded by the freeze seal top flange, use of a separate coolant passage in the top flange results in a more reliably operating seal. Addition of this chamber in no way restricts the free movement of the coils. Cooling load for this type of design is about 10% higher than for the double-helix type. The increase is probably caused by the better thermal conductivity of the lower region due to the sodium present between the coils.

The stationary freeze seal on the pump case has a straight annulus 20 in. in diam., with walls spaced about ⅛ in. apart on the radius. The cooling jacket is on the outer wall only, located about 7 in. above the bottom of the annulus.

The experimental data consistently have yielded cooling loads for this design which are about two to three times that expected by thermal conduction alone. A similar configuration was investigated at Mine Safety Appliances Company (*1*) and it has been reported that thermal convection in the annulus is responsible for transferring the additional heat, and that the addition of three to five barrier rings in the annulus spaced about 2 in. apart reduced most thermal convection effects.

Valves may be converted easily for freeze seals; however, freeze seals are currently applied only to the larger sizes to save space and reduce cost. The freeze seals glands for valve stems differ from pump shaft glands mainly in that the cooling passages are integral with the valve bonnet. The stuffing box usually supplied on a valve is placed too close to the process liquid to allow the use of a replaceable gland such as that employed on pump shafts; therefore, a new bonnet is fabricated which incorporates the cooling passages placed as far out as practicable. Since rotation or translation of the stem is slow and infrequent, there appears to be no need for providing a tapered annulus.

A 6-in. plug valve was modified with an extension bonnet after difficulty was encountered with a gland in the usual stuffing box. This valve has been tested and is shown in Figure 8. A 6-in. angle valve has been provided with a similar seal in the extended bonnet between the valve and the regular chevron packing. This valve has been operated up to 1200° F. with no difficulties. The cooling load is small. Figure 9 is a photograph of this valve showing the location of the seal at the enlargement on the bonnet extension. The enlargement is formed by a tube welded over a single Acme thread coolant passage cut into the extension. The test data for this seal are shown on Figure 10.

Feasibility of Operation

Considerable experience has been gained from the operation and testing of freeze seals. In general, they appear to be reliable and efficient. The greatest danger to seal operation is the loss of coolant supply which, of course, can result in total seal failure; therefore, extra precautions are necessary to maintain constant coolant flow. Momentary flow interruption can be tolerated since tests show that a cold seal is maintained for as long as 1¼ min. after the coolant is stopped. This permits ample time to initiate emergency flow. Once flow of liquid metal through the seal has started, stopping it, even with high coolant flows, is difficult. Therefore, the inert gas space and gas seals are designed as a backup to retard or contain temporarily the liquid-metal flow to make easier the securing of a lost seal.

The service life of a freeze seal will be indefinite if the material being sealed is free from abrasives and the coolant does not foul the cooling passages excessively. Minor adjustments in the coolant flow will compensate for ordinary fouling. Since no wear is experienced at the seal, no mechanical adjustments are required. These features make this seal particularly attractive for applications in inaccessible or radioactive areas. In addition, the relative low cost of the seal and the ease of converting commercial equipment make it attractive for accessible equipment.

The freeze-seal principle is not necessarily confined to shaft seals. It may be adopted for slip-expansion joints in piping, remotely operated freeze-off valves, instrument lead throughs, and a variety of other miscellaneous applications. Future simplification in seal design will broaden the field and increase the reliability. In particular, improvements in design will be towards allowing greater misalignment and wobble in shafts, providing heat barriers to permit natural convection cooling to the atmosphere, and devising a means to reduce the breakaway torque for rotating shafts.

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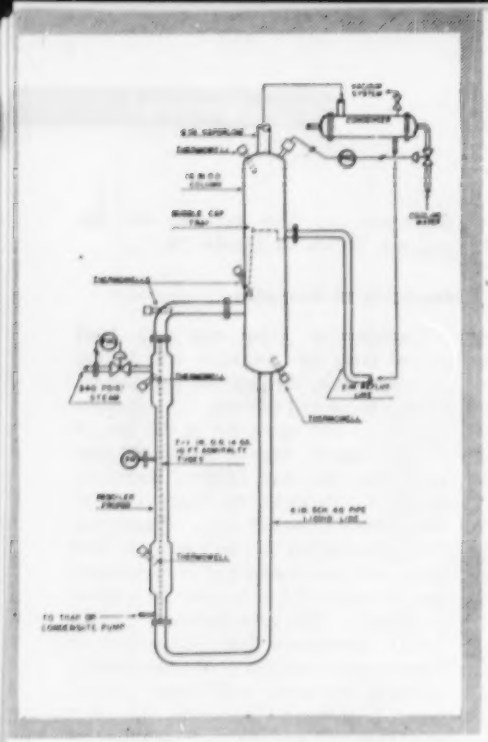

Fig. 1. Experimental thermosiphon reboiler.

Thermosiphon reboilers (natural circulation evaporators) have high transfer rates, limited space requirements, and are easily cleaned when fouled. Although widely used in the chemical industry, design data have not been readily available. Work was undertaken by the authors to obtain experimental over-all heat transfer rates and maximum allowable heat fluxes in a small thermosiphon reboiler. A number of process fluids with widely varying physical properties were studied at several pressure levels for each.

Over-all heat transfer rates as high as 2,500 B.t.u./(hr.) (sq. ft.) (°F.) and fluxes above 100,000 B.t.u./(hr.) (sq. ft.) were obtained for water at 127 lb./sq. in. abs. On the other hand, transfer rates less than 200 B.t.u./(hr.) (sq. ft.) (°F.) were obtained with ethyl toluene at 2.0 lb./sq. in. abs. Other process fluids gave intermediate results. Vapor-lock points were noted, and proper operating techniques to obtain maximum loadings are suggested.

A table giving Celanese Corporation of America reboiler standards is included.

Design Data for Thermosiphon Reboilers

D. C. Lee, J. W. Dorsey, G. Z. Moore, F. Drew Mayfield

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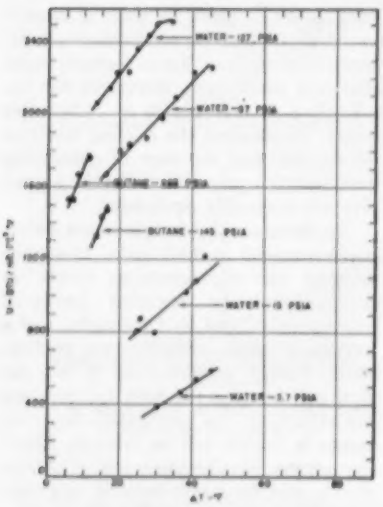

Fig. 2. Experimental thermosiphon reboiler. Data on 10-ft. long, 1-in. O.D. tubes.

Thermosiphon reboilers (natural circulation vertical tube evaporators) have been used for years in the chemical industry because of their high heat transfer rates, limited space requirements, resistance to some types of fouling, and ease and completeness of cleaning when fouled. However, little has been published on heat transfer coefficients and maximum allowable heat fluxes (Q/A) for thermosiphon reboilers. Design procedures have been unsatisfactory, especially with regard to the estimation of maximum allowable fluxes.

Operating data on plant reboilers at the Celanese Corporation Chemcel plant showed some surprisingly high heat transfer rates and indicated that in many cases economies in construction could be realized if more accurate data were available on the maximum allowable fluxes. Therefore, an experimental program was initiated to develop basic design data for thermosiphon reboilers.

Experimental Equipment and Its Operation

The equipment used in the experimental work is shown in Figure 1.

The reboiler proper consisted of seven 1-in. O.D. × 14-gauge Admiralty tubes. 10 ft. long, inside of a 10-ft. section of 4-in. schedule 40 pipe. The reboiler was attached to a 16-in. O.D. column containing one bubble-cap tray. The reboiler liquid line consisted of approximately 9 ft. of 4-in. schedule 40 pipe plus two schedule 40 long sweep ells. The vapor nozzle was a 4-in. schedule 40 long sweep ell. Two glass windows were located at right angles to and at the same level as the reboiler vapor nozzle.

The column vapors were sent to the shell side of a large shell and tube condenser where they were condensed and returned to the column as reflux on the bubble-cap tray. The pressure in the vapor space of the column was controlled by a pressure recorder-controller setting the cooling water flow to the tubes of the shell and tube condenser. No absolute values of temperatures were measured, but the pressures in both the reboiler steam chest and the process side vapor space were recorded. The temperature difference between the steam and the mixture of vapor and liquid leaving the reboiler was recorded directly by means of a Brown Electronik temperature difference recorder with the use of iron-constantan thermocouples. Provision was made also, by means of a multicontact switch, for measuring the temperature difference between the reference thermowell (in the upper of the two enlarged sections of the reboiler steam chest) and the other thermowells shown in Figure 1. Steam of 240 lb./sq.in. gauge was trapped to remove condensate and then throttled through the control valve so that it entered the reboiler steam chest superheated. It was thought that some temperature difference might exist between the upper and lower ends of the reboiler steam chest, but no measurable temperature difference was

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found during operation. Also, after thermal equilibrium had been attained (as indicated by constant reading of the temperature difference recorder and pressure recorders) less than 1° F. variation in the temperature difference between the reference thermowell and any of the other thermowells in the column or the vapor nozzle could be found. It is believed that the maximum error in the temperature differences measured was never greater than 5% of the reported value.

Sufficient liquid was kept in the system to maintain the liquid level in the column near the reboiler top tube sheet, which corresponds to normal plant operating practice. No significant change in heat transfer rates was found when this level was lowered 18 in. with the heat input and column vapor space pressure held constant. The effect of liquid level was not studied sufficiently to warrant any further conclusions.

That portion of the column below the bubble plate—the liquid line, the reboiler proper, and the vapor nozzle—were all well insulated with 2 in. of 85% MgO insulation. The steam input to the reboiler was determined by collecting and weighing the condensate from the reboiler over a measured period of time with calculated corrections being made for the flash steam loss from the condensate. Heat losses from the equipment were felt negligible compared to the errors inherent in measuring the heat input.

The steam chest temperature was taken from Keenan and Keys (*2*) as the temperature corresponding to the measured steam chest pressure. The process side vaporization temperature was arrived at by subtracting the recorded temperature difference from the steam chest temperature. The heat input to the column was computed from the corrected rate of condensate formation and Keenan and Keyes' (*2*) values of the enthalpy change from saturated 240 lb./sq.in. gauge steam to saturated liquid at the reboiler chest pressure. The heat input divided by the reboiler tube area (17.9 sq. ft.) and the temperature difference gave the over-all heat transfer coefficient values reported.

Results

For each of the liquids tested, a number of runs were made at each of several pressure levels. Experimental results are presented graphically in Figures 2-4. More complete data at the points of maximum heat flux are given also in Table 1. In some cases quite high U values and heat fluxes were obtained, the highest U value being about 2,500 B.t.u./(hr.)(sq.ft.)(° F.) and the highest flux being above 400,000 B.t.u./(hr.)(sq.ft.).

Trouble would normally be expected in obtaining good reproducibility in the high U value range since small fouling resistances become dominant. Schweppe and Foust (*4*), in reporting high film coefficients for liquid heating under forced circulation conditions, noted the pronounced effect of tube surface condition on high experimental film coefficients. In the present study, however, excellent reproducibility was obtained on the data for water at 14.7 lb./sq.in.abs. in Figure 2. These data on water were the first determinations made in this study. Six months later, after completing all of the data presented in Figure 2, except that for butane, the data were reproduced almost exactly.

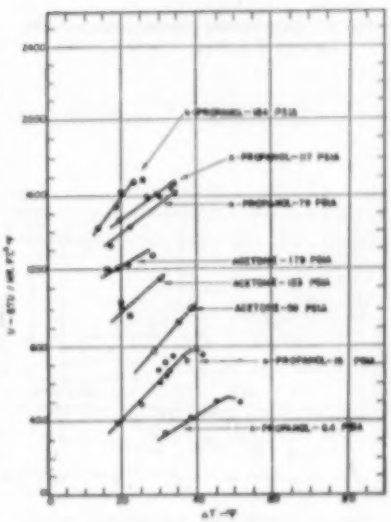
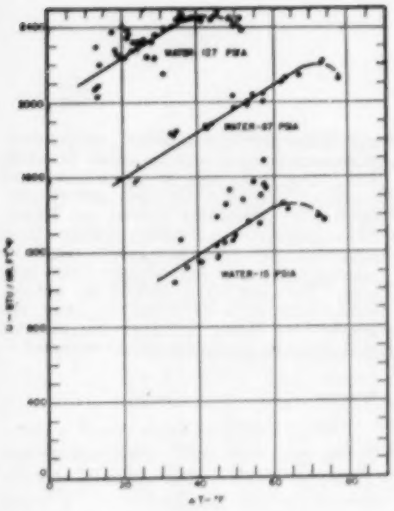


Fig. 3. Experimental thermosiphon reboiler. Data on 10-ft. long, 1-in. O.D. tubes.

Table 1.—Operating Variables at Maximum Heat Flux

	Run	Process Pressure, lb./sq.in.abs.	Steam Pressure, lb./sq.in.abs.	Temperature Difference ° F.	Heat Load M B.t.u./hr.	Maximum Flux, M B.t.u./(hr.)(sq.ft.)	U B.t.u./(hr.)(sq.ft.)(° F.)
water	1	127	185	31	1,397	78.0	2,520
	2	67	126	45	1,835	102.5	2,280
	3	14.7	34.6	45	980	54.8	1,228
	4	3.68	10.3	44.5	466	26.0	585
acetone	5	180	118	28	632	35.3	1,270
	6	123	88	33	662	37.0	1,120
	7	58	32.0	37	662	37.0	1,000
propylene glycol	8	7.28	63.1	70	637	35.6	510
	9	3.69	180	80	573	32.0	400
	10	1.59	149	105	546	30.5	290
n-propanol	11	183	215	23	693	38.7	1,680
	12	117	149	31	941	52.6	1,700
	13	79	102	32.5	948	53.0	1,630
	14	14.7	27.8	38	537	30.0	790
ethyl toluene	15	14.7	159	41	448	25.0	610
	16	8.23	110	51	399	22.3	440
	17	4.85	87	62	322	18.0	290
	18	1.96	52.4	82	278	15.5	190
benzene	19	132	203	37	794	44.3	1,200
	20	75	209	42	761	42.4	1,010
	21	14.7	20.0	41	404	22.6	550
	22	9.65	14.7	47.5	376	21.0	440
	23	4.9	6.87	57	367	20.5	360
n-butane	24	265	26.8	12	372	20.8	1,750
	25	145	8.65	14.5	371	20.7	1,450
water (5-ft. tubes)	26	127	207	40	860	98.0	2,450
	27	67	178	72	1,390	158.0	2,200
	28	14.7	46	64	816	93.0	1,450

Fig. 5. Experimental thermosiphon reboiler. Data on 5-ft. long, 1-in. O.D. tubes.



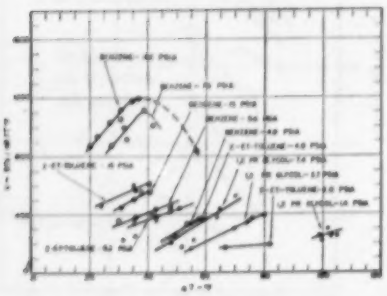


Fig. 4. Experimental thermosiphon reboiler. Data on 10-ft. long, 1-in. O.D. tubes.

VAPOR LOCK

From some of the curves of Figures 2-5 it can be seen that after increasing to a certain point, the overall heat transfer coefficients began to decrease with further increase in temperature difference. These are the transfer rates at which the reboiler began to vapor-lock.

All of the runs were continued to the vapor-lock condition and the topmost point on each curve represents this point. Up to the vapor-lock condition, the circulation of liquid and vapor through the reboiler was apparently smooth and continuous; above this point a surging type flow occurred. Visual observations as to the type flows were made through the two glass windows at pressures below 15 lb./sq.in. gauge. At higher pressures the glass windows were replaced by blind flanges and the vapor-lock point was determined by listening.

While water was boiling at atmospheric pressure in the reboiler, it was found that additional heat could be put into the reboiler even after it was vapor-locked, but that much greater temperature differences existed than would have been necessary if smooth circulation had still been going on in the reboiler. Once vapor locking began with water, steam flow to the reboiler could be reduced to a value below that at which the vapor lock commenced and smooth circulation would start again. However, with butane as the process fluid, once the reboiler vapor-locked, the steam chest pressure would go up to the line pressure (240 lb./sq.in. gauge) and the steam input would drop to approximately one quarter of what it had been just prior to vapor lock. To restore good operation required that the steam rate be reduced to approximately 10% of what it had been at the vapor-lock point. Once circulation was again established the steam rate could be increased up to any point below the vapor lock. These two cases are the extremes and the other materials studied gave intermediate behavior.

A limited number of runs was made with 5-ft. long, 1-in. tubes to determine whether the shorter tube lengths gave appreciably different results. The data are presented in Figure 5. The results were not greatly different from those with the 10-ft. tubes except that the values of maximum flux were somewhat greater. Because time was limited a comprehensive comparison of the two tube lengths was not made.

PULSATION

The visual observations of the material leaving the vapor nozzle of this experimental reboiler showed a mixture of liquid and vapor emerging at high velocities. The same observations were made also through windows on a 5-ft. distillation column with an 800-sq. ft. thermosiphon reboiler when both water and propylene glycol were reboiled.

In an effort to understand better the cause of these high velocities, a small laboratory, single tube glass thermosiphon reboiler was built and operated. Heat was supplied by means of an electrical heating element wrapped around the tube. Slow-motion moving pictures of the unit showed very plainly a rapid pulsating flow in the tube with each slug of liquid and vapor leaving the tube at high velocity. Each pulse of mixed liquid and vapor leaving the top of the tube was accompanied by a "kickback" of the liquid in the bottom of the tube.

Comparisons and Limitations

Piret and Isbin (*3*) have reported boiling heat transfer coefficients for an electrically heated 1-in. tube, vertical natural circulation evaporator for water, isopropyl, and *n*-butyl alcohols, carbon tetrachloride, and potassium carbonate solutions. Although maximum or limiting fluxes were not reported, the transfer coefficients themselves seem to be in line with this work, when it is considered that the values reported were for the boiling film alone. By measuring the boiling film coefficient and the recirculation rate, Piret and Isbin were able to correlate their data using an empirical Dittus-Boelter form of equation.

A recent study by Guerrieri and Talty (*1*) presents data on five organic liquids in vertical natural circulation reboilers. They present a correlation of the boiling film coefficient as a function of two-phase convective heat transfer with a factor applied to correct for the increase in film coefficient resulting from nucleate boiling. Although no data are presented on maximum allowable fluxes, these data and observations support the following conclusions reached in the present study: first, that convection in a thermosiphon reboiler must be one of the main processes for transferring heat; second, that the high heat transfer rates are the result of the high, two-phase flow velocities observed leaving the outlet vapor nozzle; third, that the so-called vapor locking which limits the maximum heat flux obtainable can be explained through the observations made of these high velocities and the pulsing-type flow observed in the small glass reboiler.

During normal operation the liquid entering the bottom of the tubes is slightly below the boiling point because of the hydrostatic head of liquid above it. Upon entering the tube the liquid is heated to its boiling point. Heat transfer rates are lowest in this section. As bubbles form the laminar film is agitated and heat transfer rates are increased. Further formation of bubbles reduces the apparent density of the liquid in the tube, allowing the superheated liquid toward the bottom of the tube to flash. As vapor thus begins to be generated rapidly, a large volume change occurs which accelerates the mixture of liquid and vapor out the top of the tube. Velocities become high and heat transfer rates are correspondingly high. Thus, heat transfer rates always increase along the length of the tube from entrance to outlet. The performance of a thermosiphon reboiler in this manner is described and correlated by Guerrieri and Talty (*1*).

The observed high outlet velocities in thermosiphons and the pulsing flow in the small, single-tube thermosiphon offer an explanation of the phenomenon of vapor locking which limits the maximum heat flux in a thermosiphon reboiler. The velocity of the vapor-liquid mixtures observed coming out of the vapor nozzle is so great that it cannot be accounted for on the basis of difference in densities between the liquid in

the pot and the vapor-liquid mixture in the tubes. However, accepting a pulsating-type flow in each tube, recoil energy is available for accelerating the liquid and vapor up and out of the tube. This was observed in the small glass tube reboiler; as the mixture of liquid and vapor was accelerated upward, a corresponding recoil, or "kickback," was observed in the bottom of the tube. This means that the flow through any one tube in a reboiler is not a smooth continuous flow but actually is a pulsating flow. The total flow from a number of tubes, however, gives the appearance of being a smooth flow. The vapor lock, or surge, point is probably reached when the "kickbacks" are great enough to cause slugs of vapor to be pushed back into the bottom head and liquid line.

Correlation

Correlations of the experimental data on maximum flux and heat transfer coefficients at maximum operating capacity are presented in Figures 6 and 7. The maximum flux values were taken from the curves of experimental over-all heat transfer coefficient vs. temperature difference at a point between the break in the straight line and the maximum U. The data were compared first by plotting maximum flux against the vapor-liquid density ratio. Many of the resulting curves had a hump, the location of which seemed to be affected by surface tension. Consequently, maximum flux was plotted against a form of the Kelvin equation, used in the correlation as follows:

$$\left[\frac{\rho_L - \rho_v}{\rho_v}\right]\frac{N}{\sigma}$$

This equation related the pressure due to the surface tension on the concave interface of radius N, (of a newly formed bubble, in this case) and the densities of the two phases. Plotting maximum flux against the Kelvin equation tended to bring the "humps" of the curves to a common position along the abscissa, although the curves were still displaced along the ordinate. As a further refinement, the heat capacity and square root of length terms were added to obtain the present form of the primary independent variable, which is plotted as the abscissa.

In order to unify the family of curves, a term was inserted in the ordinate with maximum flux representing the superheat required to flash a liquid. The superheat was assumed to be the value estimated from the Clapeyron equation with the vapor pressure derived by the Kelvin equation described previously, and is equivalent to $2\sigma T/N\rho_L H_v$. In order to give the best correlation, it was necessary also to use the liquid density, temperature, Prandtl number, and square root of the tube length in the ordinate term to adjust the curve to its present form, which is presented in Figure 1.

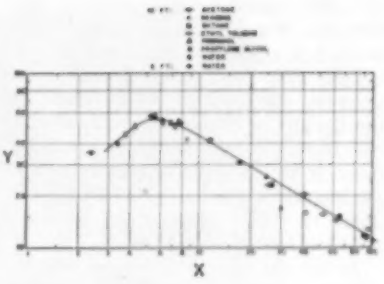


Fig. 6. Experimental thermosiphon reboiler. Correlation of maximum flux.

$$X = \left(\frac{\rho_L - \rho_v}{\rho_v}\right)\left(\frac{1}{\sigma C_p}\right)\left(\frac{L}{10}\right)^{0.5}$$

$$Y = \frac{(U\Delta T)(HM_v)}{(\sigma T^2)}\left(\frac{C_p\mu}{K}\right)^{-0.5}\left(\frac{L}{10}\right)^{0.5}$$

A second correlation which was attempted was that of the boiling film coefficients at the point of maximum flux. The heat transfer rate at the limiting flux condition is of value in design problems because it permits an estimate to be made of the steam chest pressure required to obtain the maximum capacity of the reboiler. The correlation presented in Figure 6 is of value to the design engineer in this manner although it was necessary to make certain simplifying assumptions in its derivation. Therefore, the correlation is probably not as theoretically sound as the more generalized correlations given by Guerrieri and Talty (*1*).

In an attempt to correlate heat transfer coefficients at the points of maximum flux, it was found that the abscissa term from Figure 1 could be plotted against the Prandtl number and Nusselt number in the ordinate, with appropriate exponents for heat transfer equations, to obtain a fair correlation. Since it was not possible to measure the individual film coefficients in the experimental reboiler, the process side coefficient was estimated from the over-all U value by subtracting out the metal resistance and an assumed steam coefficient of 5,000 B.t.u./(hr.)(sq.ft.)(° F.).

Standard heat transfer equations for forced convection cases usually describe the Nusselt number as a function of Reynolds and Prandtl numbers in a manner similar to the following:

$$N_u = C(R_e)^{0.8}(P_r)^{0.33}$$

However, special cases sometimes defy the evaluation of Reynolds number, as in the case of free convection. The dimensionless Grashof number has been used successfully in the past as a modification of the Reynolds number in cases involving free convection.

A similar situation appears to be involved in thermosiphon reboiler mechanics, which is complicated by unsteady and nonuniform conditions of fluid flow. In lieu of a theoretically derived dimensionless term, the variable plotted along the abscissa in Figures 1 and 2 is used as a substitute for the Reynolds number until further refinements are made possible by additional data. For practical purposes, the abscissa term finally arrived at appears to describe both heat transfer and mechanical effects which limit the flow of fluid at maximum flux.

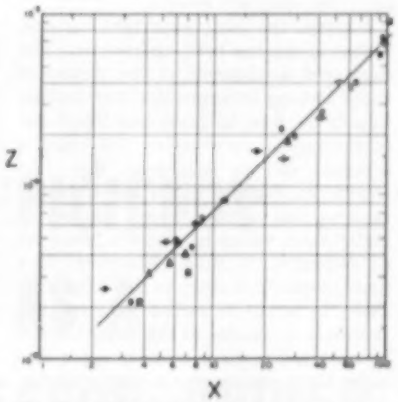


Fig. 7. Experimental thermosiphon reboiler. Correlation of process film coefficients.

$$X = \left(\frac{\rho_L - \rho_v}{\rho_v}\right)\left(\frac{1}{\sigma C_p}\right)\left(\frac{L}{10}\right)^{0.5}$$

$$Z = \left(12\,\frac{hd}{K}\right)^{-1}\left(\frac{C_p\mu}{K}\right)^{1/3}$$

No attempt has been made to evaluate the radius of the newly formed bubble (N) obtained in the Kelvin equation. Since N is theoretically dependent on the size of a nucleus on which the bubble forms, the roughness of the tube wall can be expected to affect this value. It is probable, however, that the effect of roughness is limited by the rapid kinetics of ebullition, and therefore roughness can probably be ignored in standard types of smooth wall reboiler tubing. In any event, because of lack of experimental data, (N) was used as a constant assumed value of 1.0.

It may be noted that the maximum flux correlation contains certain terms on both the X and Y axes of Figure 1. However, there is no simple way to eliminate these terms because the curve is not straight on a log-log plot.

Design and Operating

Because heat transfer rates and maximum allowable fluxes in a thermosiphon reboiler are undoubtedly a function of the physical characteristics of the reboiler as well as the physical properties of the fluids, it is recommended that the data presented in this study be used with a safety factor in the design of large reboilers. The only physical characteristic which was evaluated in this study was tube length, and even on this point the data are limited.

Perhaps the most important variable is that of the top head and nozzle. The suggested mechanism of the causes of vapor locking indicates that any restriction to the flow of vapor and liquid out of the top of the reboiler will cause a decrease in the maximum flux. As shown in Figure 1, the experimental reboiler had a long sweep ell for an outlet head, which produced a minimum of resistance to flow. However, in a more typical design, as in Figure 8, there is more resistance to flow, and therefore a reboiler of this design would be expected to have a lower vapor-lock point than the experimental reboiler. The experimental data and correlations of this paper have been checked against a few plant reboilers of the type in Figure 8, and their maximum fluxes before vapor locking actually were lower than the predicted values by factors of about 0.6 to 0.8. Therefore, for design purposes, it is recommended that the values for both the maximum flux and the film coefficient at the limiting flux be multiplied by a factor of 0.6.

The variables leading to vapor locking also suggest that anything that can be done to increase the resistance to "kickback" will permit higher fluxes before vapor locking. This point has been checked qualitatively in plant reboilers in a few cases by two different approaches. First, the use of higher liquid levels has apparently increased the allowable flux. Second, the use of a restriction, such as an orifice plate, in the liquid line to the bottom head also has increased the maximum allowable flux. It seems apparent that more experimental data are needed on the variables of tube length, tube diameter, nozzle sizes, and head design.

In the use of these data for reboiler design, it should be noted that the data are for Admiralty tubes and the corresponding U values for carbon steel or stainless tubes are materially less in the higher ranges. Caution is advised in designing reboilers for U values much in excess of 500 B.t.u./(hr.)(sq.ft.)(° F.) due to the pronounced effect of a small amount of fouling; for example, a fouling factor of 0.0005 B.t.u./(hr.)(sq.ft.)(° F.) will drop a U value of 1,000 down to 667 B.t.u./(hr.)(sq. ft.)(° F.).

It is thought that good operating practice for a thermosiphon reboiler is as follows:

1. Establish a liquid level in the column approximately level with the top tube sheet of the reboiler before turning on steam.
2. Gradually increase the steam rate to the desired operating point. A rapid increase in steam rate would probably cause the reboiler to vapor-lock much below the limiting flux.
3. If the reboiler should vapor-lock (as evidenced by either a rapid increase in reboiler steam chest pressure or by audible surging) then the steam rate to the reboiler should be reduced to such a point that either the audible surging stops or the chest pressure goes down to the value it had before the sudden increase was noticed. Then the steam rate can be slowly increased to the desired operating level.

A typical reboiler design is outlined in Figure 8 along with a condensed table of Celanese standards on reboiler design. Fixed tube sheets are used here in all cases; in the case of 10-ft. tube lengths an expansion bellows is included in the shell. Wear plates (formed from the dropout from cutting manhole openings) are usually installed opposite the reboiler vapor nozzle as a protection against erosion of the column wall.

Notation

Cp = specific heat of liquid, B.t.u./(lb.)(° F.)
d = tube I.D., ft.
h = film coefficient, B.t.u./(hr.)(sq.ft.)(° F.)
H_v = latent heat of vaporization, B.t.u./lb.
K = thermal conductivity, B.t.u./(hr.)(ft.)(° F.)
L = tube length, ft.
M_v = molecular weight of vapor, lb./lb. mole
T = temperature, ° R.
U = over-all heat transfer coefficient, B.t.u./(hr.)(sq.ft.)(° F.)
$(U\Delta T)$ = heat flux, B.t.u./(hr.)(sq.ft.)
σ = surface tension, dynes/cm.
ρ_L = liquid density, lb./cu.ft.
ρ_v = vapor density, lb./cu.ft.
μ = viscosity, lb./(hr.)(ft.)
N = radius of newly formed bubble, Kelvin equation

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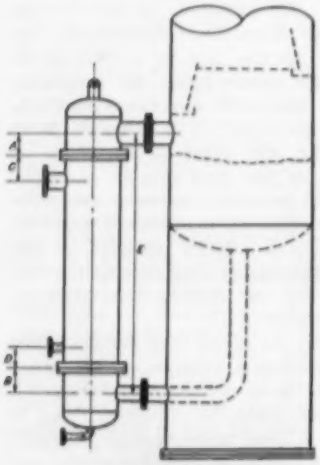
Fig. 8. Typical Celanese Corporation thermosiphon reboiler design standards.



SHELL OD	NO. TUBES	TUBE SHEET FACES	APPROX. AREA	NOZZLE SIZES				DIMENSIONS				
				VAPOR	LIQUID	STEAM	COND	A	B	C	D	E
16"	108	4'-11 1/4"	192 sq.ft.	6"	4"	4"	1 1/2"	7 13/16"	5 13/16"	8"	5 3/4"	6'-1 3/4"
20"	176	4'-11 1/4"	215 sq.ft.	8"	6"	4"	2"	8 15/16"	7 13/16"	8"	5 3/4"	6'-4 3/4"
24"	272	4'-11 1/4"	333 sq.ft.	10"	6"	6"	3"	9 13/16"	7 13/16"	9"	7 3/4"	6'-5 3/4"
30"	431	4'-11 1/4"	527 sq.ft.	12"	6"	6"	3"	11 7/16"	7 13/16"	9"	7 3/4"	6'-7 1/4"
36"	601	4'-11 1/4"	735 sq.ft.	16"	8"	8"	4"	13 1/16"	9 15/16"	10 3/4"	8"	6'-11"
24"	272	6'-7 3/4"	448 sq.ft.	10"	6"	6"	3"	9 13/16"	7 13/16"	9"	6 3/4"	8'-1 3/4"
30"	431	6'-7 3/4"	710 sq.ft.	12"	6"	6"	3"	11 7/16"	7 13/16"	9"	6 3/4"	8'-3 1/4"
36"	601	6'-7 3/4"	990 sq.ft.	16"	8"	8"	4"	13 1/16"	9 15/16"	10 3/4"	8"	8'-7"
42"	870	6'-7 3/4"	1400 sq.ft.	16"	10"	8"	4"	17 11/16"	10 15/16"	10 1/16"	6 11/16"	9'-0 1/2"
30"	431	9'-11 3/4"	1065 sq.ft.	12"	6"	8"	3"	11 7/16"	7 13/16"	9"	6 3/4"	11'-7 1/4"
36"	601	9'-11 3/4"	1520 sq.ft.	16"	8"	8"	4"	13 1/16"	9 15/16"	10 3/4"	6 3/4"	11'-11"
42"	870	9'-11 3/4"	2180 sq.ft.	16"	10"	8"	4"	17 11/16"	10 15/16"	10 1/16"	6 13/16"	12'-4 1/2"

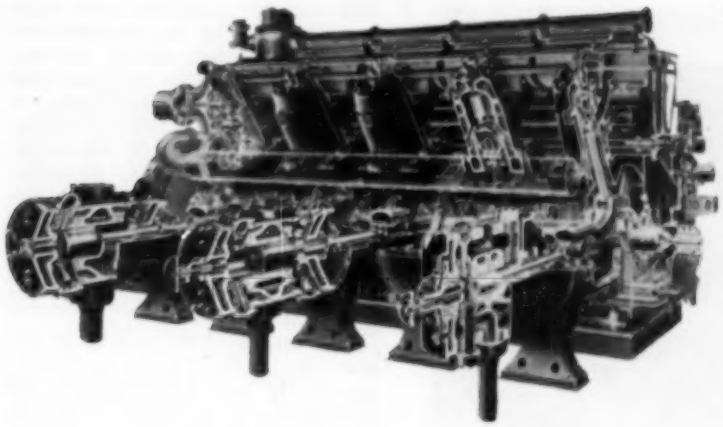


Fig. 1. Type GMVA compressor engine.

This discussion reviews the history of engineering development of modern gas engines having high performance and low-fuel consumption. The progress made is based on sound fundamentals and is attractive from the economic viewpoint. The general discussion of compressors driven by such engines is merely an introduction to the many facets involved. Use of this type of machinery is growing in the chemical industries, and the present trend of fuel and power costs helps to justify construction of chemical plants near the sources of natural gas where maximum advantage of the high efficiency engine may be realized.

HIGH EFFICIENCY ENGINE AS A COMPRESSOR DRIVER

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The chemical industry is placing more emphasis on operating economy and flexibility in its evaluations of "packaged power" equipment. With the increased availability of gaseous and low-grade oil fuels since World War II and with the migration of the chemical industry to the geographical areas where these fuels are produced, it is understandable that high efficiency engines have received favorable attention for compressor drives. How this modern engine drive meets the criteria of optimum economy and flexibility will be discussed in this paper.

The Two-cycle Gas Engine

Until the mid-1940's the best two-cycle gas engines for compressor drives were rated at 60 b.m.e.p. (brake mean effective pressure) at speeds up to 300 rev./min., at fuel consumption rates of about 10,000 B.t.u./b.hp./hr.

Since that time improvements have been effected in combustion chamber design, cylinder porting, and fuel-gas injection. Reciprocating scavenge pumps have been replaced by centrifugal scavenge pumps, both gear driven and exhaust turbine driven. Progress also has been made in burning natural gas at higher compression ratios than previously had been deemed possible. Detonation is avoided by keeping the air cooler as it enters the power cylinders.

The latest version of the Cooper-Bessemer type GMVA compressor engine is shown in Figure 1. It is a 14-in. bore by 14-in. stroke engine, rated 135 hp./cyl. at 300 rev./min. Scavenging air is compressed by an efficient gear-driven centrifugal blower. Figure 2 shows its fuel consumption rate for variable b.m.e.p. and at full-load rating it is 7,500 B.t.u./b.hp.-hr.

A larger 18-in. bore by 20-in. stroke type GMWA unit of similar construction is shown in Figure 3. It is rated at 250 hp./cyl. at 250 rev./min. Its fuel consumption rate is slightly better as shown in Figure 4 and at full-load rating it is 7,350 B.t.u./b.hp.-hr.

This performance demonstrates real progress in engineering developments within the relatively short period of less than ten years.

Not only was fuel consumption reduced and ratings increased, but it has also been possible to attain other economies. Less heat is wasted to the cylinder walls and to the exhaust, resulting in a much lower heat loss to the cylinder and manifold water jackets, requiring less auxiliary equipment investment for items such as radiators or cooling towers.

A picture of the saving in heat-dissipation equipment may be seen by reviewing the performance of the 14-in. bore by 14-in. stroke GMVA unit. Its predecessor

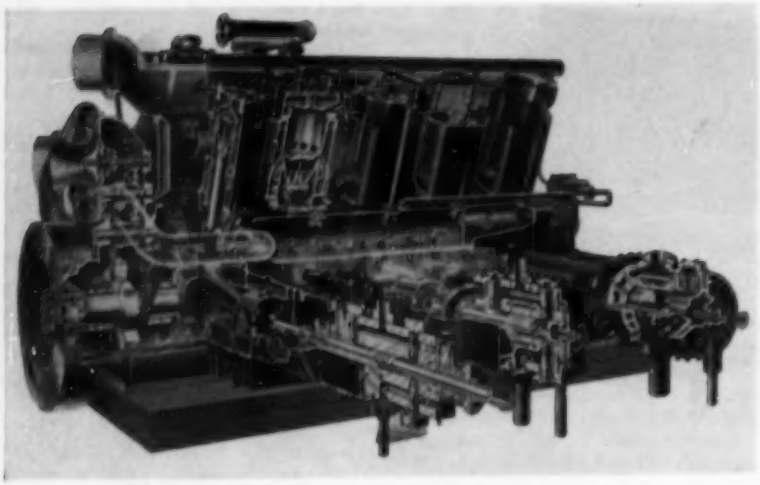


Fig. 3. Type GMWA compressor engine.

of the same bore and stroke had a heat transfer rate of 2,900 B.t.u./hp.-hr. to the cooling water and 650 B.t.u./hp.-hr. to the piston cooling oil. A 10-cyl. engine was rated 1,000 hp. The improvements made on this unit reduced these heat transfer rates to 1,700 and 460, respectively while enjoying an increased rating of 1,350 hp. The earlier construction required equipment to handle 2,900,000 B.t.u./hr. for the jacket water and 650,000 B.t.u./hr. for the oil system for a unit size of 1,000 hp. The modern unit, requiring no more space rated at 1,350 hp., needs heat-dissipation equipment to handle 2,295,000 B.t.u./hr. for the jacket water and 621,000 B.t.u./hr. for the oil system. The jacket water heat-dissipation rate is reduced 21% while enjoying a horsepower rating increase of 35%. These are real economies in installation and operating costs.

Four-cycle Gas Engine

In the mid-thirties, Cooper-Bessemer licensed the application of the Buchi system of supercharging the diesel engine by the use of the exhaust gas turbine-driven centrifugal blower. Engine ratings were increased by packing more pounds of air into the cylinders so that more fuel oil could be burned. Use of supercharged diesel engines grew and reached all fields. The higher ratings resulted in more horsepower in a unit of space and therefore less cost per horsepower for foundations and building, or for housing in vessels, locomotives, etc.

Table 1.

Type of Engine	Rating in B.M.E.P.	Heat Dissipation B.t.u./bhp./hr. jacket water	lube oil
Low compr. gas engine	70	3900	450
Atmospheric diesel	80	2200	450
Supercharged diesel	145	1300	365
Supercharged gas-diesel	145	1300	285
Supercharged gas engine	145	1300	285

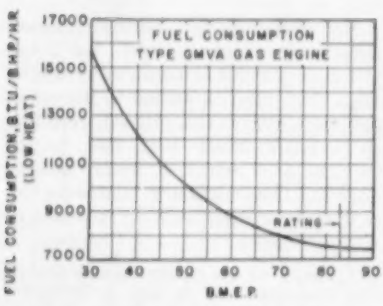


Fig. 2. Specific fuel consumption of Type GMVA engine.

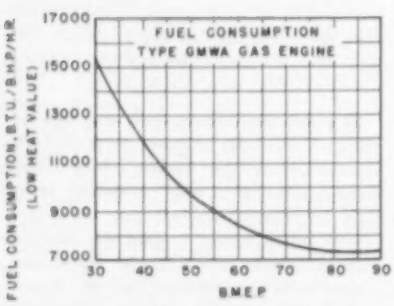


Fig. 4. Specific fuel consumption of Type GMWA engine.

As the price of fuel oil increased in the postwar period the gas-diesel engine was developed. Natural gas was introduced in the intake air stream just ahead of the cylinder intake valve. A small amount of diesel fuel was injected as in the full diesel and the engine operated smoothly with no detonation resulting from the high compression ratio used in the diesel. Self-ignition of the gas did not occur because, at diesel compression ratios, the mixture was much leaner than required for ignition by heat of compression.

Why not replace the pilot diesel fuel used for ignition with an electric spark? By careful development and strengthening of the ignition system the supercharged four-cycle gas engine became a reality. Performance of the supercharged gas-diesel and the supercharged spark-ignited gas engine was practically identical.

An important development during the last four years involved refinements in the supercharging process. Research led to cooling the engine intake air so that still higher pressures could be tolerated without detonation.

This permitted using higher compression ratios with correspondingly improved ratings and fuel-consumption rates.

Figure 5 shows the high efficiency gas engine driving a multistage compressor in a chemical plant. This particular engine is a 15½-in. bore by 22-in. stroke usually turning 327 rev./min. and is built in 6-, 8-, V12-, and V16-cyl. combinations. Figures 6, 7, and 8 show the fuel consumption rates of this engine when operating as a supercharged diesel, gas-diesel, and spark-ignited gas engine, respectively.

The two gas-burning versions of engine, at a rating of 145 b.m.e.p., operate with a thermal efficiency of nearly 41%. This is an efficiency level attained by no other type of prime mover. Combine this with a plant location in geographical areas where natural gas is produced (or delivered at minimum cost) and one has power produced at unusually low cost.

The four-cycle engine requires less heat-dissipation equipment. Progress in this area is shown in Table 1 by the change from 3,900 B.t.u./hp.-hr. for the old, low-compression gas engine rated at 70 b.m.e.p. to only 1,300 B.t.u./hp.-hr. for the supercharged version at 145 b.m.e.p.

Table 1 shows that this development for an 8-cyl. 15½-in. bore by 22-in. stroke engine turning 327 rev./min. resulted in its horsepower output being increased from 960 to 1,990 or 107%, while the cooling equipment for the jacket water decreased from 3,750,000 B.t.u./hr. to 2,590,000 B.t.u./hr. or a reduction of 31%. The heat transfer to the lube oil (which is used as the piston coolant) increased slightly from 432,000 B.t.u./hr. to 567,000 B.t.u./hr. The total heat to be dissipated decreased from 4,182,000 B.t.u./hr. to 3,157,000 or a reduc-

tion of 24½% for the 107% increase in power output.

Economics

The previous discussion has centered around performance. It is extremely difficult to present relative economics of chemical plant compressor installations for various types of prime movers because of variations dependent on geographical location which may affect fuel or power costs, the process involved, size of plant, etc.

Some highlights of one economic analysis are shown in Table A (8,000 hp. in compressor units required).

The summary in Table A indicates fewer expenditures per year for the high efficiency engine-driven compressor of $289,400. The difference of $800,000 in original investment is paid out in 2.76 yr. Other studies will show different results, but the high efficiency engine will usually be attractive, particularly in areas of low fuel cost.

Fig. 5. Type LSV-16 engine driving reciprocating compressors in a chemical process plant.

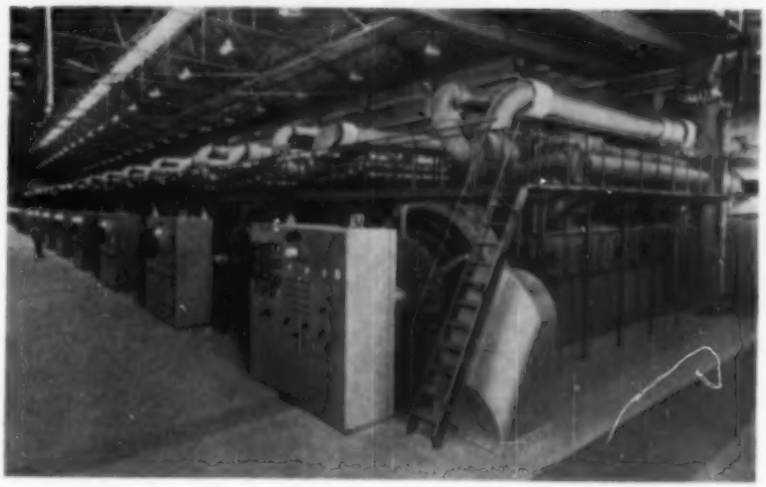


Table A.

Installed cost of engine-driven compressors at $250/hp.	$2,000,000
Installed cost of motor-driven compressors at $150/hp.	$1,200,000
Operating cost of engine-driven compressors:	
engine maintenance at $1/hp./yr.	$ 8,000
compressor maintenance at 0.90/hp./hr.	7,200
fuel at $0.20/1000 cu.ft.	87,600
lube oil at $1.10/hp./yr.	8,800
fixed charges at 13% (taxes, insurance, depreciation, interest, etc.)	260,000
Total operating cost per year	$371,600
Operating cost of motor-driven compressors:	
motor maintenance at $0.35/hp./yr.	$ 2,800
compr. maintenance at $0.90/hr./yr.	7,200
power cost at $0.009/kw.-hr.	495,000
fixed charges at 13%	156,000
Total operating cost per year	$661,000

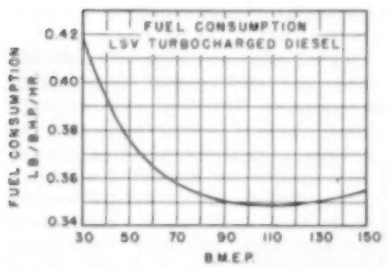


Fig. 6. Specific fuel consumption of Type LSV-16 supercharged diesel engine.

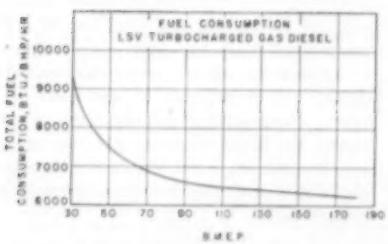


Fig. 7. Specific fuel consumption of Type LSV-16 supercharged gas-diesel engine.

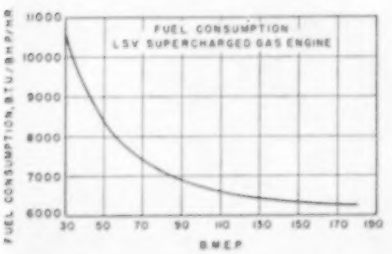


Fig. 8. Specific fuel consumption of Type LSV-16 supercharged spark ignited gas engine.

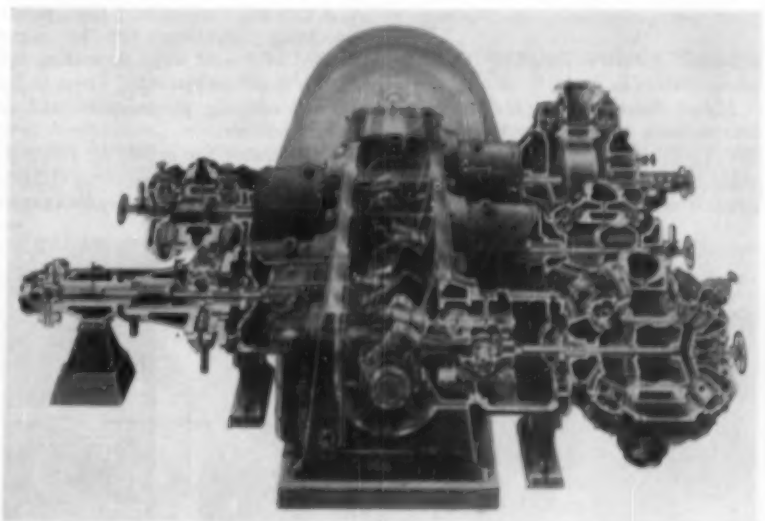


Fig. 9. Type JM power driven compressor unit.

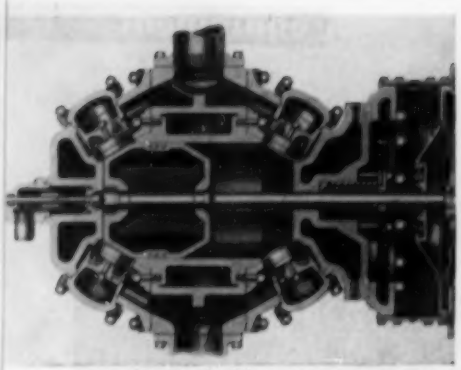


Fig. 10. Standard low pressure compressor cylinder.

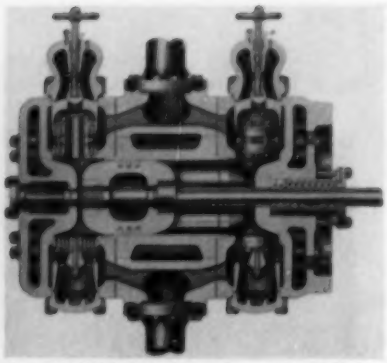


Fig. 11. Medium pressure compressor cylinder.

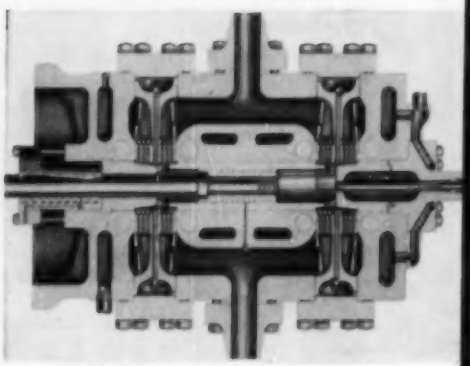


Fig. 12. Medium to high pressure compressor cylinder with tie bolt construction.

Compressors

Figure 9 illustrates a typical compressor that can be motor driven or engine driven. This illustration also shows various types of compressor cylinders that may be applied for different services. Other types of cylinders are available for the many processes used in the chemical industry including pressures above 20,000 lb./sq.in.

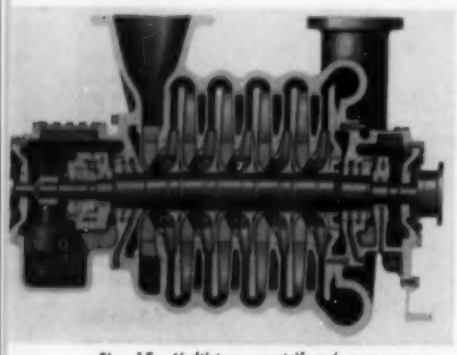


Fig. 15. Multistage centrifugal compressor.

Figure 10 shows a typical design for low-pressure compressor cylinders. Figure 11 illustrates medium-pressure-design construction utilizing Meehanite gray iron up to its tolerable pressure limit and nodular iron at the higher pressures that this stronger material endures. In this illustration are shown different valve arrangements to indicate the flexibility available with single- and double-deck valves with various sizes of unloaders enabling operation at various pressures and minimum valve velocities.

Figure 12 is a different design for medium to high pressure service with the severe stresses caused by the varying cylinder pressures reduced by prestressing the material in compression through use of tie bolts in the critical zones. This feature is used in several Meehanite, nodular iron, cast steel, or forged steel constructions.

HIGH PRESSURES

Extremely high pressures are handled be employing a forged-steel-plunger-type compressor as shown in Figure 13. The plunger is made of extremely hard nitrided steel to withstand the wear induced by the packing under such high pressures.

Automatic unloading for varying operating conditions can be accomplished in several ways, depending upon the service requirements. These include suction opening valves, pneumatic unloader pockets, etc.

One scheme for providing automatically operated variable-volume clearance is shown in Figure 14. A pilot-operated hydraulic cylinder positions a bronze-ringed piston within a chamber in the outer cylinder head of the compressor cylinder. The position of the piston controls the clearance volume of the outward stroke of the compressor piston to suit the volume requirements.

CENTRIFUGAL COMPRESSORS

There are many processes that lend themselves to the use of centrifugal compressors. Pressures and volumes required for the process being used may indicate a desirability of using a centrifugal compressor instead of a reciprocating compressor. A 5-stage compressor is shown in Figure 15. When driven by the high efficiency gas engine through step-up gears a high over-all efficiency is attained. Decision as to whether centrifugal or reciprocating compressors should be used for a particular process must be made by studying and comparing the engineering and economics facts for each case. There is no definite set of circumstances that dictate the preference of one over the other. Such studies usually disclose the use of the high efficiency gas engine as a prime mover, whether the driven machine is a centrifugal or a reciprocating compressor.

Presented at A.I.Ch.E. meeting, Lake Placid, New York.

Fig. 13. Extremely high pressure plunger-type compressor cylinder.

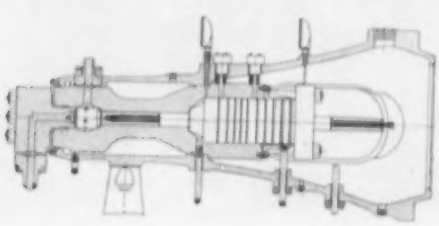
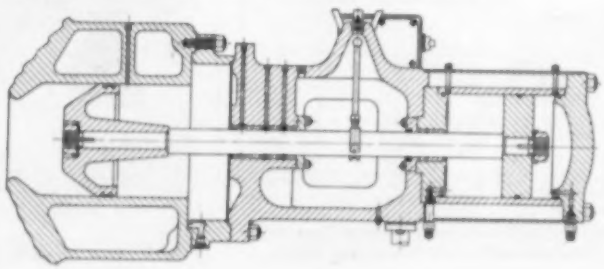


Fig. 14. Hydraulically operated variable clearance pocket.



Aerial view of a portion of Baton Rouge's billion-dollar industrial area.

NEW ORLEANS—LAST CALL!

Last-minute developments expand and enhance National Meeting for May 6-9

Baton Rouge trip main feature

Everything is now ready at New Orleans. New Orleans and Baton Rouge Sections, co-sponsors of the meeting, are braced to give the big welcome to invading chemical engineers—and their ladies. For the ladies the program is set, the technical sessions have had their final polishing with no changes in the offing, the night clubs and restaurants have their doors open and the tables dusted. All that remains is to pack your bags and come to New Orleans.

There's going to be a television program on Sunday afternoon, May 6, on a theme closely related to the panel discussion of "Financial Aid to Colleges." Presented by Tulane University, in cooperation with A.I.Ch.E., the program will last a half hour, will dramatize the advantages of choosing a scientific career, will also bring out the present-day shortage of scientific and engineering graduates. Certainly there is a crying need for more programs like this today. Chemical engineers will do well to be on hand to see the program, evaluate its contribution and the practicality of many such programs throughout the country.

A special all-day Monday meeting, May 7, is planned for Local Section chairmen and vice-chairmen, (Council members are also expected to attend.) Tentative topics are: a report of the Membership Committee presented by the chairman, J. J. McKetta; and a presentation and discussion of the work of the Professional Development and Dinsmore Committees.

Then, W. E. Lobo will talk on E.J.C. and A.I.Ch.E.'s participation in it. Engineers' Council for Professional Development will be discussed by W. L. McCabe, and last year's A.I.Ch.E. president, B. F. Dodge, will discuss the latest developments in the new Engineering Center project.

There will be a luncheon for those attending, and considerable discussion of the problems of communication between the national organization and the local sections, the operational and financial problems of the local sections.

We've said just about all we could say about New Orleans and Baton Rouge in the February and March issues. If you're not convinced it's time to come to New Orleans, you never will be—and, frankly, we think you would make a big mistake by not coming. We'll see you there.

Did you see the announcement of a Liquid Metals Discussion Session (p. 58, March C.E.P.)?

Those interested in participating in an informal discussion of individual problems, who have not contacted Prof. Bonilla at Columbia, should do so even though the original deadline of April 20 is passed. If this is inconvenient, he should be contacted at the New Orleans meeting, well before the discussion session on the 9th.

TWO TEAMS—ONE MEETING

Two teams can be better than one, particularly when they have the spirit and drive of the co-sponsoring groups for the New Orleans meeting. Teams behind the forthcoming meeting are the Baton Rouge and the New Orleans Local Sections.

Each has a meeting general co-chairman and other staff members who occupy posts on various committees. Members of the two teams that could be caught recently by the camera are shown in the accompanying photographs.

UNUSUAL PLANTS TRIP TO BATON ROUGE AREA

The attention of C.E.P.'s readers is invited to the day-long plants trip that will take chemical engineers and guests to the Baton Rouge industrial area—one of the outstanding concentrations of process industries in the U. S. Four plants are to be visited: Ethyl, Esso, Kaiser Aluminum, and Allied's Solvay. Trip will take place Monday, May 7th.

Some of the members of the Baton Rouge team are, (l. to r.), L. J. Governale, vice-chairman, Entertainment; J. W. Melancon, Program; Alfred Smith III, chairman, Registration; M. O. Gernand, vice-chairman, Hotel & Meeting Rooms; B. S. Pressburg, co-vice chairman, Arrangements; E. A. Gaskill, vice-chairman, Printing; L. H. Stephens, co-chairman, Arrangements; J. A. Polack, chairman, Plant Trips; Mrs. L. J. Governale, co-chairman, Ladies Program; H. E. O'Connell, chairman, Technical Program; and R. H. Bretz, chairman, Finance.

Some of the members of the New Orleans team: (l. to r.), (seated), Walter Godcheaux, Jr., co-chairman; John R. Tusson, coordinator, Ladies Program; Edwin R. Cousins, secretary; Henri J. Molaison, chairman, Printing; Alton S. Hall, vice-chairman, Finance; (standing) Carl W. Peters, co-vice chairman; and John H. Bryant, chairman, Entertainment.

THE PROJECT ENGINEER

PART II

What types of companies, who in those companies, participated in the survey? In this second part of C.E.P.'s report on the survey, these details are given as well as those on special training, the consulting engineer, the savings made by using a project engineer.

Carl W. Barkow

College of Business Administration
University of Tennessee

When it comes to salaries, responsibility, training, how does the project engineer fare in relation to the type of chemical or petroleum company he is in, and the size of that company? Table 1 gives the answer to this.

At the same time, when considering the results of a survey such as this, the type of sample, the position of the man answering the questionnaire, are important for proper evaluation. (See Tables 2 and 3.)

The questionnaire, on which the survey results are based, was sent only to those companies which were likely to have an engineering division, and which were expanding. A definite attempt was made to exclude companies under 500 employees, since few such companies use project engineers in the true sense of the term. The questionnaire was pretested, but probably should have included a question on the amount being spent by the company for expansion.

In most cases very little relation was found between the size or type of company and either the characteristics, salaries, or positions of the project engineers or the engineering department. In

(*Continued on page* 54)

Table 1.—Years of Experience Required of Project Engineer, Type of Company, Size of Company, Degree of Responsibility, Salary, and Training

Type of Company	Size of Company	Complete Responsibility	Salary Ranges in $/Month: Asst. Proj. Engr.	Salary Ranges in $/Month: Project Engineer	Formal Training
Three Years Experience Required					
Soaps & Detergents	100–500	yes	.....	700–800	no
Pharmaceutical	500–1000	yes	.....	500–600	no
Refining '	36,000	no	no answer		no
Atomic Energy	100–500	yes	500–700	600–800	no
Chem. Manuf.	1000–5000	yes	no answer		no
Synthetic Rubber	1000–5000	yes	500–600	500–600	yes
Distillery	1000–5000	no	500–600	600–900	no
Four Years Experience Required					
Synthetic Fibers	5000+	yes	no answer		yes
Refining	4020	yes	500–600	600–700	yes
Five Years Experience Required					
Atomic Energy	5000+	no	600–700	700–800	no
Refining'	30,000+	no	500–800	700–1000+	yes
Soaps & Detergents	5000+	yes	700–800	800–900	no
Petrochemical	1500	yes	500–700	600–900	no
Chem. Manf.	6000	no	500–600	700–800	yes
Plastics	4000	yes	500–700	600–800	no
Refining'	5000+	no	no answer		no
Resins	525	yes	500–800	700–1000+	yes
Atomic Energy	1000–5000	yes	varies widely		.....
Pharmaceutical	1000–5000	yes	600–700	800–900	.....
Refining'	5000+	no	600–700	800–900	no
Explosives	1000–5000	no	.....	600–700	no
Plastics	1000–5000	no	300–600	800–900	yes
Chem. Manuf.	1000–5000	yes	500–700	700–900	yes
Chem. Manuf.	1000–5000	yes	600–700	700–800	no
Refining	520	no	no answer		no
Refining'	5000+	no	500–700	600–800	no
Refining'	5000+	yes	600–700	700–800	no
Atomic Energy	3500	no	.....	500–600	yes
Atomic Energy	3000	yes	no answer		yes
Refining'	8000	yes	500–600	600–800	yes
Petroleum Chem.	1000–5000	.....	no answer		no
Chem. Manuf.	500–1000	yes	600–700	700–800	no
Chem. Manuf.	1000–5000	yes	500–600	600–800	no
Ten Years Experience Required					
Refining'	1000–5000	no	500–700	700–800	yes
Synthetic Fibers	5000+	yes	700–800	1000+	no
Synthetic Fibers	12,000	yes	500–600	700–800	yes
Synthetic Rubber	2500	yes	500–600	600–700	no
Chem. Manuf.	10,300	yes	800–900	900–1000+	yes
Photographic Organic Chem.	5000+	yes	800–900	1000+	yes
Chem. Manuf.	5000+	yes	.....	800–900	no
Distillery	2000	no	700–800	800–900	yes
Refining	2400	no	600–800	700–900	yes
Heavy Chem.	5000+	no	no answer		yes
Chem. Manuf.	100–500	partial	600–700	700–900	no
Refining'	1000–5000	yes	500–600	600–700	yes
Petrol. Additives	3,930	yes	no answer		yes
Pharmaceuticals	1000–5000	yes	no answer		yes
Electro-Chem.	5000+	yes	no answer		no
Fifteen Years Experience Required					
Refining'	1000–5000	yes	600–800	1000+	yes
Chem. Manufac.	1000–5000	yes	.....	600–700	yes
Chem. Manuf.	600	no	700–800	1000+	no
Electro-Chem.	1000–5000	yes	500–600	800–900	no
Heavy Chem.	5000+	yes	.....	1000+	no
Refining	450	yes	700–800	1000+	no
Glass	5000	yes	500–600	800–900	no
Refining'	1000–5000	yes	700	1000+	no
Synthetic Filters	5000+	.....	no answer		no

' These are major refineries also engaged in petrochemical production.

INTALOX SADDLE PACKING

In the five years since Intalox saddle packing was first presented to chemical engineers as a uniquely new and different tower filling material, it has earned widespread acceptance.

Its better HTU values has permitted reduced tower heights resulting in savings in construction costs; its lower pressure drop has permitted savings in initial investment in blowers and pumps and substantial reduction in operating costs; its higher flooding limits have permitted higher liquid and gas rates.

This improved performance stems from the unique, patented shape of Intalox — a shape which makes possible maximum contact area between liquid and gas with minimum resistance to gas flow. A comparison of published data shows that size for size, Intalox offers: a greater number of pieces per cubic foot, a greater total surface area per cubic foot, a higher percentage of free space and less weight. Of even more importance than the greater physical surface area offered by Intalox is the fact that virtually all of the greater area is *accessible* surface area. For no two pieces of Intalox can "nest" to render ineffective any significant portion of the packing.

Intalox saddle packing is manufactured in white chemical porcelain and in chemical stoneware. It is made in six nominal sizes: ¼", ⅜", ¾", 1", 1½" and 2". Full technical data is given in Bulletin S-29, free on request.

U. S. STONEWARE

AKRON 9, OHIO

(Continued form page 52)

general the larger companies seemed to give less responsibility to the project engineer, require a higher educational standing, keep a closer budget check, give more special training, and pay a bit more, but the differences were so slight as to be quite inconclusive.

The author believes that an additional 95 replies would not change the trends and conclusions found in this study and that the results in both Parts I and II are typical within the chemical and petroleum industries, always remembering that the smaller companies have been excluded for the purpose of the study.

Savings Made

Without going into the actual amount of money saved, the companies were queried as to the areas in which savings were made by using the project engineering concept. Of the companies queried, 86 answered the question, with 75 emphasizing savings in design coordination, 68 in field coordination and construction, 67 in scheduling, 47 in determining the scope of the project, and 35 in purchasing and procurement. Once again the project engineer's greatest value seemed to lie in design, construction and scheduling.

Table 2.—Companies Answering Questionnaire

(By Type of Major Production)

Major Chemical Manufacturers (DuPont, Carbide, Dow, etc.)	9
Other Chemical Manufacturers	18
Refining (Most also Petrochem.)	29
Pharmaceuticals	7
Atomic Energy	6
Plastics	5
Petrochemical	4
Synthetic Fibers	4
Synthetic Rubber	3
Gasoline	3
Distilleries	2
Electrochemical	2
Soaps & Detergents	2
Glass	1

The Consulting Engineer

From the survey it seemed that the companies use consulting engineers only sparingly (61 said no, 8 sometimes, and only 23 said they used them). However, here was a problem of semantics. If engineering-construction firms are considered to be "consulting engineers," then the companies made great use of them (See table in Part I, March 1956). But if, as the questionnaire assumed, a consulting engineer is one who is a specialist in some non-construction phase such as process design, equipment development, water treatment, etc., then they are used very little. The question remains, where do these specialists get their fees? It would seem to be a field for further study.

Special Training

Of the 95 companies which answered the questionnaire, 56 do not give any type of special training to a project engineer, 31 do, and 8 declined to answer. Of the 31 "yes" answers, 23 give training before the engineer takes his position and 14 after.

The means employed for this training were many, with special coaching being the most popular. Giving the would-be project engineer the position of "assistant" seemed to be considered the next best approach, with company courses following. Seminars were next in order of frequency of use, and college courses pulled up the rear. The fields of training were varied, with planning, organization, human relations, and budget being the most important in the view of the companies.

Table 3.—Positions of Persons Who Replied to Questionnaire

Vice President (Eng'g, Manuf., etc.)	7
Director, Manager, Supt. of Engineering Division	16
Plant Manager, Plant Superintendent, Refinery manager, etc.	17
Chief Engineer	29
Plant Engineer	4
Manager of Project Eng'g., Construction & Eng'g., etc.	7
Project Engineer	3
Administrative Asst.	5
Personnel or Industrial Relations Manager, etc.	5

Here, size of company had a considerable bearing. Only 4 of the 31 companies with training programs were under 1000 employees, and 17 in the over 5000 group. Training costs money, time, and considerable effort, and this probably accounts for the larger companies doing more of it.

Nevertheless, the fact that the majority of companies do not have formal training for the position seems to be in opposition to the accepted trend today, and probably could also be studied more thoroughly to advantage.

Status of Engineering Division

Covered briefly in Part I, the position of the engineering department within each company is important enough to warrant greater detail. In Table 4, it is clear that the majority of engineering departments or divisions do not have general management status, i.e., headed by a vice-president or some official who reports directly to the president.

To see the import of this, it must be noted that in these same companies the great majority of production or manufacturing divisions, and industrial relations divisions, have such general management status.

Further, in Table 4, a comparison is made between the results of this survey, limited to engineering divisions within chemical and petroleum companies, and those of a National Industrial Conference Board survey for engineering divisions in all types of companies. The results show a definite tendency for the chemical and petroleum industries to give less status to engineering divisions than industry in general.

It does not require proof that the higher level of status a division has within a company, the more effective its operation, authority and decision-making power will be.

The tendency shown in this survey would certainly stand further study.

Table 4.—Status of Engineering Division

NICB Report No. 139 (All Industries) Engineering Division				Author's Study (Chem. & Petroleum) Engineering Division		
General	Division	Department	Employees	General	Division	Department
1	..	2	Less than 1000	6	8	6
2	4	6	1000–5000	9	21	8
21	10	7	Over 5000	17	14	4
24	14	15	Total	32	43	18
46%	27%	27%	% of Total	35%	45%	20%

C I on stream at SOHIO

180 ton-per-day Nitric Acid Plant designed and built by C & I for Sohio at Lima, Ohio.

This plant is one of many large capacity, single unit plants recently completed by C & I. They operate in excess of 345 days a year with excellent overall efficiency and minimum production costs. If you are considering nitric acid facilities it will pay you to consult C & I.

250 ton-per-day Ammonium Nitrate Solutions Plant designed and built by C&I for Sohio at Lima.

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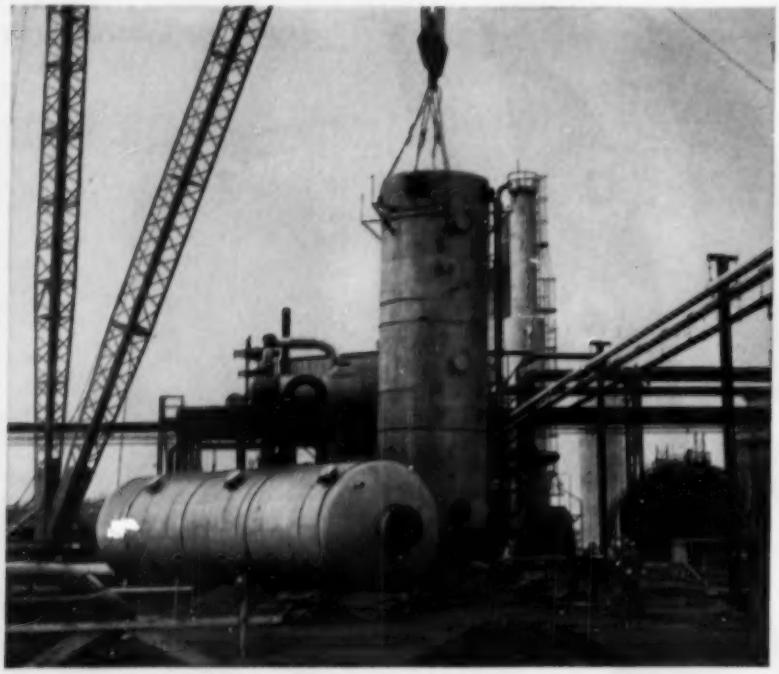

More than 86,680 welds in complex column by Downingtown

Diameter: 11′ 11″ I.D.

Total Height: 93′ 11″.

Material: Stainless steel, Type 304. Carbon steel skirt and base ring.

Shell Thickness: ½″ and ⅜″.

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Code Stamping: National Board and ASME. Sandblasted and pickle washed.

Downingtown welders completed more than 86,680 separate stainless steel welds during fabrication of this stainless steel column. Tolerances of ±⅛″ . . . ±1/16″ . . . even ±1/32″ . . . were maintained in the shaping, positioning and welding of thousands of stainless steel parts. Lapsed time from drawing board to final field testing: less than six months.

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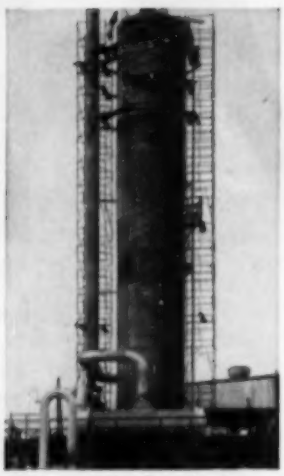
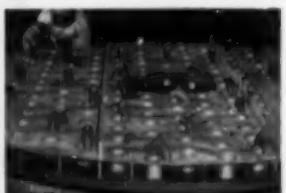


Field tested by Downingtown... inspected by customer and Hartford...Code stamped on location.



Special jig for welding stainless steel risers to stainless steel tray.

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CONTAINERS AND PRESSURE VESSELS FOR GASES, LIQUIDS AND SOLIDS

"DOMESTICATED" REACTOR AT MIT

First non-secret research reactor to be constructed in New England, MIT's reactor will be used in extensive educational program.

MIT has selected ACF Industries, New York, to design its planned nuclear research reactor. As soon as the remainder of the funds are secured, and AEC and other authorities give their approval, construction will begin. Construction work will also be done by ACF Industries through its Nuclear Energy Products Division.

The reactor will be the "domesticated" type devoted to non-secret research on peaceful use of the atom. It will have a power of 1000 kilowatts, the same as that planned for the reactor being constructed at the Univ. of Michigan. It will operate at a temperature of only 104 degrees F.—cool compared to reactors which produce atomic power. In design it will be similar to one known as the CP-5 at Argonne National Laboratory, using as fuel an alloy of uranium-234 and aluminum set in a gas-proof tank of heavy water.

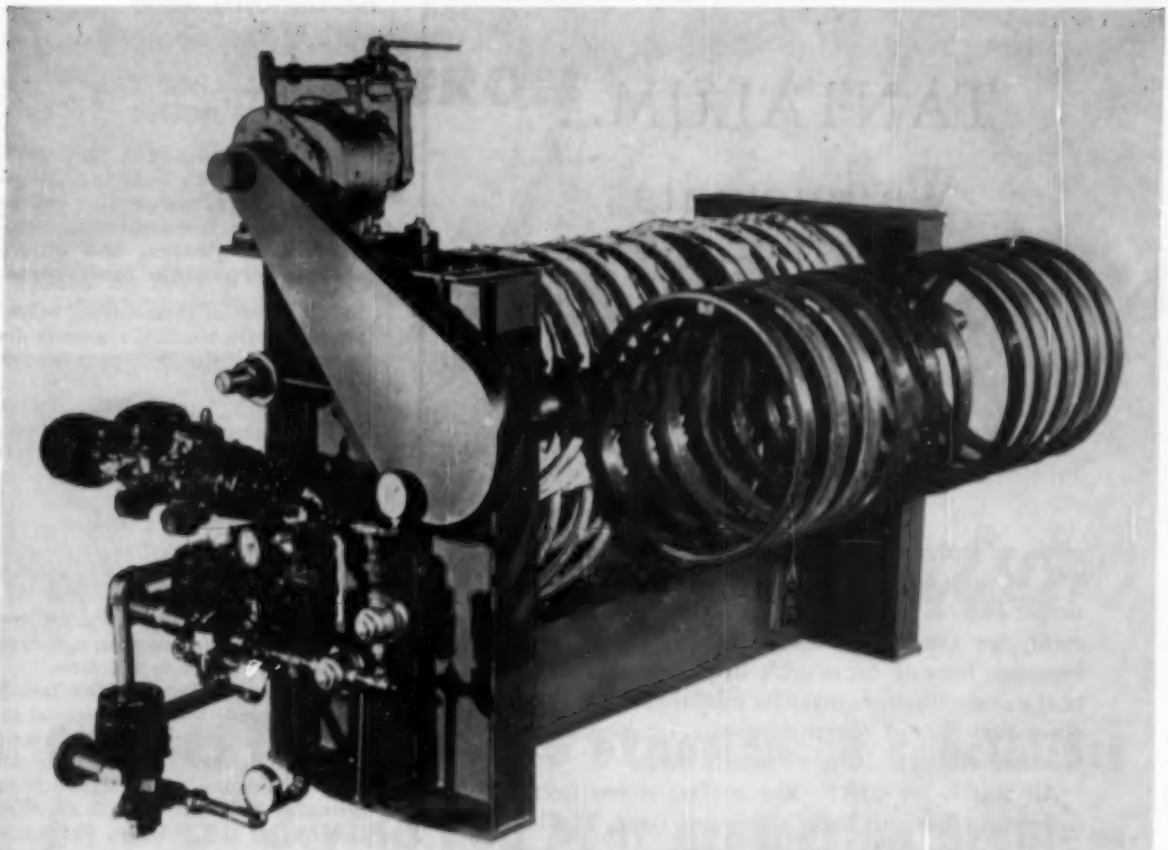
An intensive research program to develop new techniques for production of thorium metal powder has been underwritten by Metal Hydrides, Inc., and will be carried out by Batelle Memorial Institute. □

Standards in the nuclear field are coming in for considerable attention these days. The American Standards Association has begun work on national standards for the commercial and industrial use of fissionable material with a Planning Committee for Standards in the Field of Nuclear Energy under the chairmanship of Morhead Patterson, head of American Machine & Foundry.

The American Society for Testing Materials has formed a Special Administrative Committee on Nuclear Problems to investigate standards for materials and for testing materials used in nuclear energy development. □

A preliminary study contract from the Government of India for a large heavy water and nitrogen fertilizer plant to be built in northern India has been obtained by Vitro Engineering Division of Vitro Corp. This is the company's first foreign nuclear contract. □

New headquarters for General Electric's Atomic Power Equipment Department will be established in San Jose, Calif., if present plans work out.



AUTOMATIC CYCLING OF PLATE AND FRAME TYPE FILTER PRESSES

Automatic, practically continuous, filtration is now available in a plate and frame type of filter with the Eimco-Burwell Filter.

This filter developed to give a high rate of filtration on difficult, hard to filter, slurries where the particle size is measured in microns and where the filtrate must be brilliantly clear, has been used on slurries previously believed unfilterable on any automatic or semi-automatic filter.

These Eimco-Burwell filters have in many cases improved the conditions in the plant by: (1) producing a clearer filtrate, (2) increasing the capacity of the filter station on amount filtered per square foot of filter area per hour. (3) Reducing to practically zero the shut down time required for cleaning. (4) Increasing media life per ton of production. (5) Reducing the operator's physical labor. (6) Washing out more of the soluble values. (7) Upgrading the concentrate to a more salable product, and in many other ways increasing the general plant efficiency.

Let Eimco provide you with data on filtration of products similar to your own on an Eimco Filter designed to specifically handle that material.

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We make it a rule not to recommend tantalum unless it is the only right material for a particular process. And when we design tantalum equipment, we use it sparingly—an easy task in most instances because tantalum's strength and excellent heat transfer qualities make for minimum bulk. Where other materials of construction can be used in conjunction with tantalum, we specify them.

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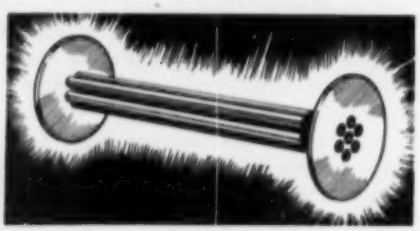

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EUROPEAN CHEMICAL ENGINEERS ACTIVE

Led by the vigorous DECHEMA (Deutsche Gesellschaft fur Chemisches Apparatewesen), equipment makers, chemical engineers, corrosion engineers, and others meet in large-scale conferences.

With a year of great activity behind them, European chemical engineers are already meeting in 1956, planning for 1957 and 1958.

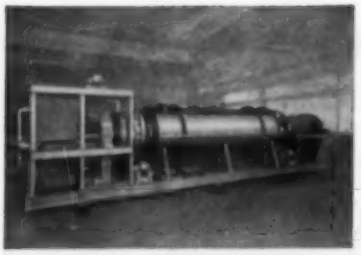
DECHEMA, sparkplug of much chemical engineering activity in Europe, will hold its own meeting in Frankfurt am Main June 6-9 on the theme of The Basic Principles of Chemical Engineering as Applied to Chemical Reactions on a Large Scale. Also in Frankfurt, May 31-June 8, DECHEMA has arranged the 12th Chemical Apparatus and Equipment Congress and Exhibition, expects European equipment companies to be out in full force.

In October the Deutsche Gesellschaft fur Metallkunde will hold a special invitational conference on The Importance of Stress Corrosion in Non-ferrous Alloys, at Frankfurt am Main. From November 22 to December 3, the First Congress of the European Federation of Corrosion will be organized and operated in Paris by the Societe de Chimie Industrielle on the occasion of the Convention of Chemical Engineering and the Fourth Salon de la Chimie.

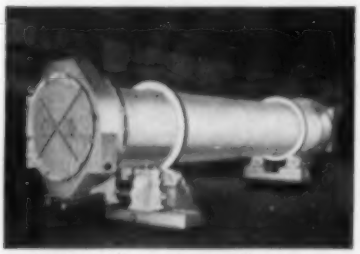
In May, 1957, the Corrosion Convention of the Arbeitsgemeinschaft Korrosion, on Passivation and the Formation of Covering Layers in the Atmosphere and in Water, will be organized by the Deutsche Gesellschaft fur Metallkunde, the Verein Deutscher Eisenhuttenleute, and the Verein Deutscher Ingenieure. In the fall of 1957 there will be a Convention of the European Federation of Corrosion in Zurich, largely a joint meeting of the Swiss societies.

In May and June of 1958 the Second Congress of the European Federation of Corrosion will probably be held at Frankfurt am Main under the auspices of the Gesellschaft Deutscher Chemiker.

A symposium on Control of Corrosion in the Chemical Industry—The Proper Use of Metals and Alloys for Corrosion Prevention, will be held at the University of Buffalo May 9 and 10. The program is directed toward the engineer who needs factual, up-to-date information for the rapid solution of everyday corrosion problems. The outstanding speakers will describe the use of metals of the future as well as those common today. □



Indirect Heat Rotary Combination Calciner and Cooler for Processing Catalyst in Hydrogen Atmosphere.



Special 60" Dia. by 32'0" Stainless Steel Dryer for Processing Plastics without Color Contamination.

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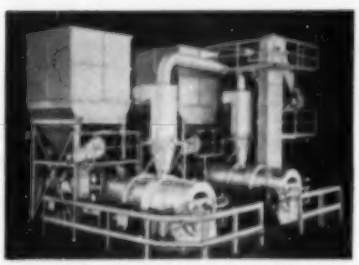
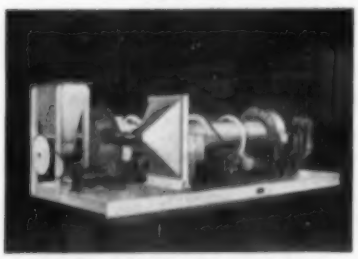


Two Completely Self-Contained Drying Systems Operated Singly or Together—Showing Materials Handling and Dust Collection Facilities.



Specially Designed Drying Unit that Removes Organic Solvent from Newly Developed Antibiotic.

Whether the material you wish to process is light or heavy, fine or coarse, abrasive or corrosive, we can design and build the exact size and type of equipment best suited for your particular product and capacity requirements.

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HIGH PRESSURE ACETYLENE PRODUCTS NOW ON COMMERCIAL SCALE

New plant will eventually produce more than 15 acetylene derivatives on a commercial scale.

When operation began recently at General Aniline & Film's new $6 million Calvert City, Ky., plant, the U.S.'s first full-scale commercial production of high pressure acetylene products went on-stream.

The result of 14 years research, pilot plant production and market development, the new plant represents an important step forward in this new field of chemical manufacturing in this country.

Acetylene, of course, has been used in chemical reactions for many years, but its use at elevated temperatures, and

(*Continued on page 63*)

North process area of new plant, with (l. to r.) asst. project director, O. W. Schnetzler; project director, F. Wuerth; vice president, P. M. Dinkins; and plant manager for entire operation, Hans Beller. Directly behind Schnetzler is a butanediol tower, behind Dinkins the two short towers are for the separation and purification of pyrrolidone and the tall one for butyrolactone, and behind Dr. Beller the towers are for propargyl alcohol.

NEW "POWERFORMING" PROCESS FOR STANDARD OIL

Standard (N.J.) will invest $60 million in new process, license plants throughout the world, claims retention of initial catalyst activity indefinitely.

"Powerforming" is the name given to the new catalytic reforming process developed by Esso Research and Engineering for its parent company. Heart of the process is a new catalyst using relatively small quantities of platinum.

One unit of the new "Powerforming" process is already on-stream at Esso's Baltimore refinery.

Two Powerformers are already on stream: Imperial Oil's at Edmonton, Canada, and Esso Standard's at Baltimore. Fourteen more are under construction, being designed or planned. These additional units are planned for Canada, Europe and elsewhere. Total cost: $60 million.

Additional units are planned by other non-affiliated companies in keeping with Esso Research's general policy of making its developments available to the entire industry under license.

The process produces gasoline capable of satisfying the needs of today's high-compression-ratio auto engines, and those of engines expected in the near future.

Basic research on the process began more than five years ago, pilot plant work demonstrating the important fact that the process had the ability to cause the desired reactions *constantly*, since its vital catalyst could be preserved for indefinite re-use by a new cleansing technique.

In brief, the new process is a fixed-bed cyclic one. It uses four, five or six reactors with three, four or five on stream while one is being regenerated by the special new technique. The cycle in any one reactor varies from five to fifteen days, the catalyst retaining its initial activity indefinitely. Feed rates are high, yields of high-octane number product are excellent.

Typical feeds for the process consist of a low-octane virgin naphtha or a cracked naphtha-virgin blend. Excellent results have been obtained with blends containing Fluid Coking naphtha. Hydrofining of feed stocks is not necessary but is generally preferred.

Table 1.—Inspections of Feed Stocks for Powerforming

	Light Arabian	Heavy Arabian	Mixed Louisiana	Heavy W. Texas
Gravity, ° API	61.9	54.0	60.3	50.6
Sulfur, wt. % *	0.03	0.07	0.005	0.20
CFR-R Octane, Clear	39	29.7	53	46.1
Distillation				
10	216	276	205	288
50	241	326	231	308
90	282	370	293	350

* Before Hydrofining.

Table 2.—Operating Results with Powerforming

	Light Arabian		Heavy Arabian	Mixed Louisiana	Heavy W. Texas
Feed Stock					
Research Octane, Clear	95	95	100	98	98
+ 3CC	100.5	100	103	103	102
Motor Octane Clear	85.5	85	88.5	88	87
+ 3CC	92	91.5	93.5	93	92
Yields					
C_5+, Vol. %	72.5	77	69	72.5	81
C_4, Vol. %	10.5	9	11.5	10.5	6.5
C_1—C_3, Wt. %	12.5	12	16.5	12	8.5
H_2, Wt. %	1.4	1.0	0.7	1.8	1.8
H_2, SCF/B	680	510	350	880	930

More PROFIT with PROCTOR!

PROCTOR DRYING RANGES OFFER:

★ Increased Yields
★ Guaranteed Product Quality
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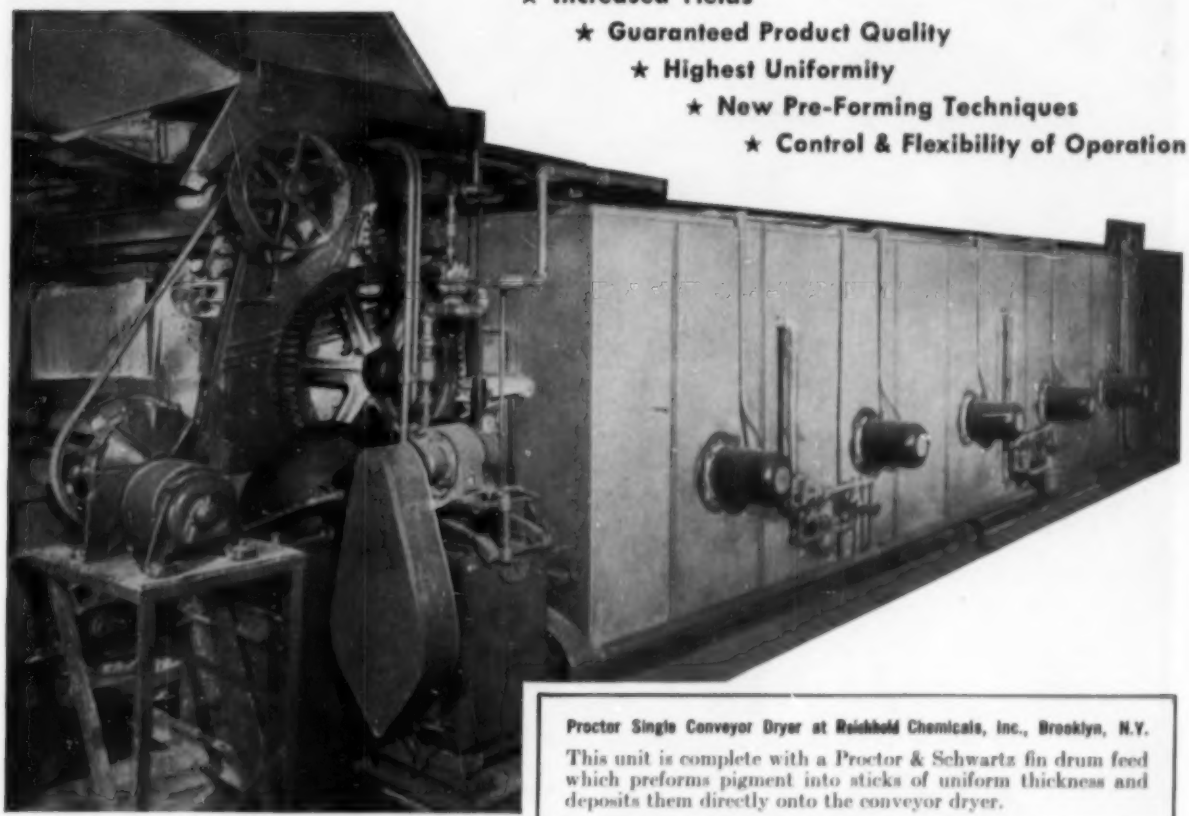
★ New Pre-Forming Techniques
★ Control & Flexibility of Operation



Proctor Single Conveyor Dryer at Reichhold Chemicals, Inc., Brooklyn, N.Y.
This unit is complete with a Proctor & Schwartz fin drum feed which preforms pigment into sticks of uniform thickness and deposits them directly onto the conveyor dryer.

Proctor Drying Ranges make possible continuous conveyor drying of many materials formerly dried by batch processing.

Use of these ranges means

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Proctor equipment carries performance guarantees based on wide experience and careful analysis of your requirements.

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PROCTOR & SCHWARTZ, Inc.

Manufacturers of Industrial Drying Equipment and Textile Machinery
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"You know Stan, it's a real pleasure working with those Pritchard fellows."

"I couldn't agree with you more!"

"Remember back when we first called Pritchard in to talk about the plans for our new plant?"

"Sure do. Why, even then they were thinking in terms of *our* problems and objectives and not theirs. The engineers they sent down to work with our staff certainly have the right attitude. Yes sir, they really know the meaning of the word 'cooperation.'"

"What has impressed me the most is their construction superintendents. You can sure tell they've had plenty of experience in the chemical industry."

"They've more than demonstrated that fact."

"Yes, sir, I'm certainly glad we chose Pritchard, again!"

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4625 Roanoke Parkway, Kansas City 12, Mo.

"You know Stan, it's a real pleasure working with those Pritchard fellows."

If you want proved ability... choose Pritchard!

Pritchard's ability to work with your engineers and designers toward a successful installation is important.

Even more vital is Pritchard's proved ability and technological skill at providing facilities for the handling of gases, liquids and solids, fractional distillation, gas absorption, evaporation, crystallization, filtration and heat transfer as they are applied in the chemical industries.

Pritchard knows *how* . . . whether you choose Pritchard as major contractor or for specialized installations.

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INDUSTRIAL NEWS

HIGH-PRESSURE ACETYLENE ON COMMERCIAL SCALE

(*Continued from page 60*)

pressures is relatively new. Begun in Germany back in 1931, work in the field was undertaken by General Aniline about 1940. Since then, at a cost of several million dollars, the company has developed its processes until the present plant now brings the highly useful products onto the large-scale commercial market, where the pilot production has already created a widespread industrial acceptance of them.

Many Products, Many Uses

Listed in the new product line already in production are:

Polyvinylpyrrolidone (PVP) widely used in cosmetics, pharmaceuticals, paints, adhesives, dyestuff applications as a stripping agent, detergents, and many other industrial applications.

PVP-Iodine effective as a bactericide, fungicide and viricide, far less toxic than other forms of iodine.

Butanediol, a basic raw material in plastics; *vinylpyrrolidone*, in glass fibers and plastics; *butyrolactone*, *pyrrolidone*, and *methylpyrrolidone*, as solvents for many diverse uses; *propargyl alcohol* and *butynediol*, highly effective corrosion inhibitors in special conditions, and *propargyl bromide*.

At present, it is clear from the above list of products, the plant will concentrate on products related to the PVP family of acetylene derivatives, but plans call for the eventual production of vinyl alkyl ethers and esters and their polymers. Some of the products already under commercial development are: methyl vinyl ether, ethyl vinyl ether, dimethyl chloracetal, polyvinyl methyl ether (PVM), and methyl vinyl ether-maleic anhydride copolymer. Major uses for these future products are as adhesives, film formers, textile sizes, and latex gelling agents.

CORRECTIONS

In the article on the Commercial Possibility of the Liquid Metal Reactor on p. 34 of the January 1956 issue, it was erroneously stated that estimated costs of electric power from this reactor were .071 cents/KWH and .065 cents/KWH. It should have read 0.71 cents/KWH and 0.65 cents/KWH, respectively.

On p. 97 of the March 1956 issue an item concerning U.S. Industrial Chemical's new "Isosebacic" acid plant placed the plant in Tuscola, Ala. It should have read, Tuscola, Ill.

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The most versatile and efficient foam killers ever developed, they increase your productive capacity; reduce processing time; eliminate the waste and fire hazard of boil-overs.

In the **PROCESS INDUSTRIES**, including textiles, paper, rubber and specialty chemicals, foam is killed with Dow Corning Antifoam* A Emulsion, or with Dow Corning Antifoam A Compound as a solvent dispersion or mixed with an ingredient of the foamer.

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For example, you need only:
1 oz. Antifoam A Compound in 62,500 lbs. of 70% caustic liquor.
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As pioneers in the filter press field, and one of the oldest and foremost manufacturers of filtration equipment, D. R. SPERRY & CO. is well qualified to evaluate your specific filtration requirements.
Sperry *Research* has categorically filed over 60 years filtration experience from continuous field reports and laboratory tests. Sperry *Engineering* applies filtration's most advanced thinking in the development of new products and new methods for obtaining better filtration at lower cost.
Working side-by-side, Sperry *Research* and Sperry *Engineering* offer today's best source of information and equipment for tomorrow's production needs.

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A complete range of styles and sizes . . . standard or special . . . for every filtration need. With center, side, or corner feed; open or closed delivery; simple or thorough washing; jacketed plates for filtering at controlled high or low temperatures.

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All types . . . all sizes. Plain or punched to your specifications. Besides cotton and paper, bases are furnished in wool, synthetics, glass and woven metals.

SPERRY Closing Devices

Sperry offers the widest range of Closing Devices to match your filter design needs. Each engineered in its own way to speed production, insure safety, save labor, and increase the life of the filter cloths. Choose from nine popular models—including the new easy-to-install HANDRAULIC and the popular EHC-L Electric Closing Device—factory installed on new Sperry Filter Presses or field installed in existing presses of any make.

Send for SPERRY CATALOG

Complete with charts, tables, and diagrams to help in the operation, maintenance and selection of filtration equipment. Write for your free copy of Catalog 7-E today.

New Handraulic Closing Device

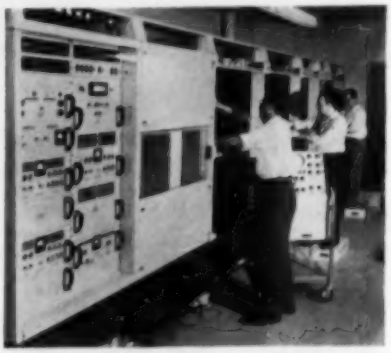
D. R. SPERRY & CO.
BATAVIA, ILLINOIS

Sales Representatives
George S. Tarbox, 808 Nepperhan Ave., Yonkers, New York
B. M. Pilhashy, 833 Merchants Exchange Building, San Francisco 4, California
Alumbaugh & McCabe, 847 E. 17th Avenue, Denver 18, Colorado
Texas Chemical Engineering Co., 4101 San Jacinto, Houston 4, Texas

NEW COMPUTER IS BIG STEP FORWARD FOR BUSINESS

There is a tendency these days for engineers to become somewhat blasé when computers are mentioned — everyone knows they are fast, vastly complicated and highly accurate. Superlatives have been thrown around like confetti at Mardi Gras. Sometimes we seem to forget computers are designed to do a job.

Datamatic Corp., Newton Highlands, Mass., a 60%-40% jointly-owned venture of Minneapolis-Honeywell and Raytheon Manufacturing, has not lost sight of this, has designed a system with an eye on the needs of the businessman and technician in industry.



Engineers check the memory section of the new coordinated high-speed data processing system.

Called the "Datamatic 1000" the new system is a coordinated data-processing system employing high-speed computer principles. In effect it is an electronic office capable of handling a wide range of clerical operations including sales analysis, inventory and production control.

It is neither miraculous nor in an ivory tower, but is designed to meet the industrial needs of business which wants a computer that can quickly accept a great mass of data, do a minimum amount of computation, and come up with all the answers in a hurry.

To do this, Datamatic has built high computer capacity, added input and output speed, and enlarged the system's memory by use of three-inch magnetic tapes which can store as much information as 465,000 punched cards. As many as 100 tapes can be incorporated, any one of which can be referred to or questioned without disturbing the rest of the system. Final reports are turned out at the rate of 6000 punched cards per hour or 900 printed lines per minute.

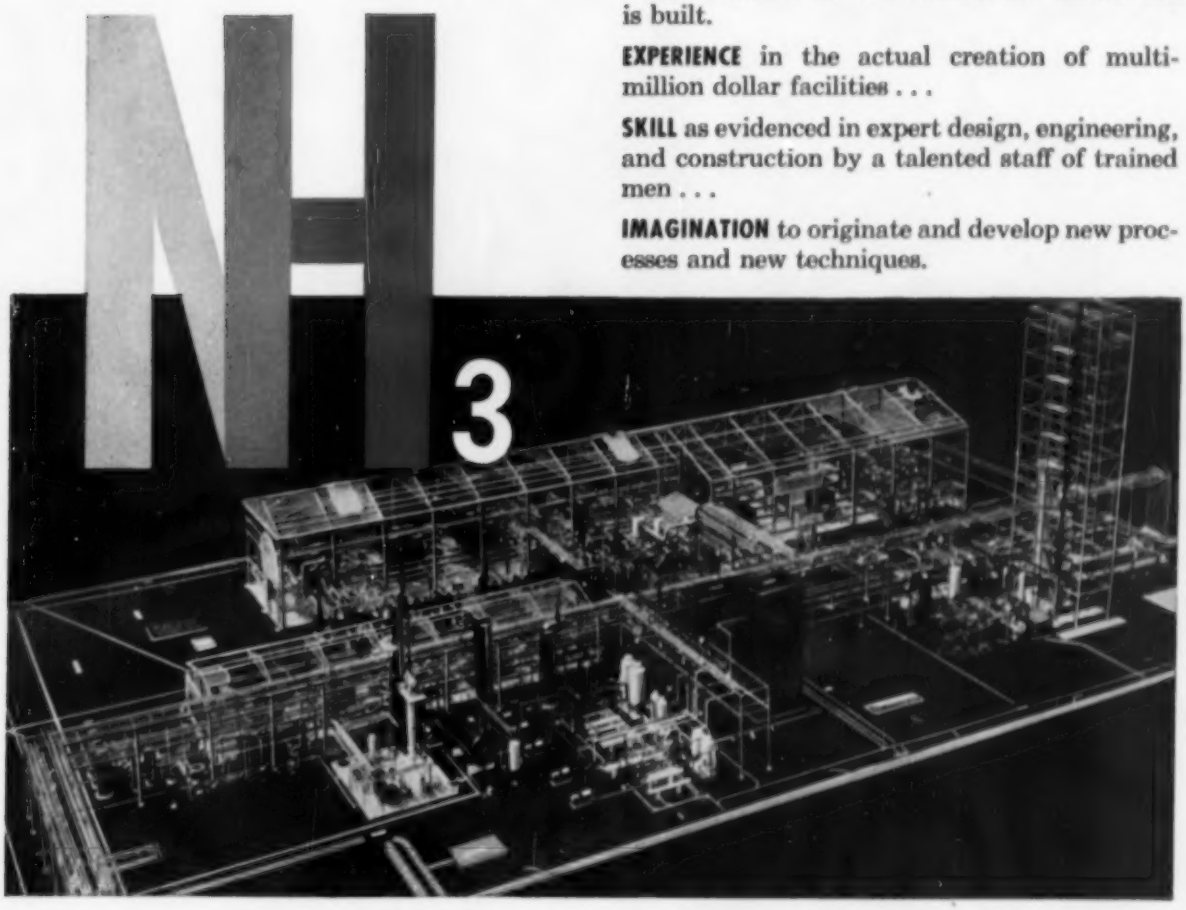
The system will sell for a minimum of $1.5 million, rent for $30,000 to $40,000 per month.

EXPERIENCE • SKILL • IMAGINATION . . . are the foundations on which modern industrial achievement is built.

EXPERIENCE in the actual creation of multi-million dollar facilities . . .

SKILL as evidenced in expert design, engineering, and construction by a talented staff of trained men . . .

IMAGINATION to originate and develop new processes and new techniques.



Imagination takes form in models. This model, made in advance of detailed design, was used throughout the engineering, procurement and construction stages of the job, and for the training of operators.

Catalytic experience, skill, and imagination put this modern 300 ton per day Anhydrous Ammonia Plant into service—ON TIME AND ON BUDGET.

With undivided responsibility, Catalytic completed process design, engineering and construction in 13 months.

CATALYTIC

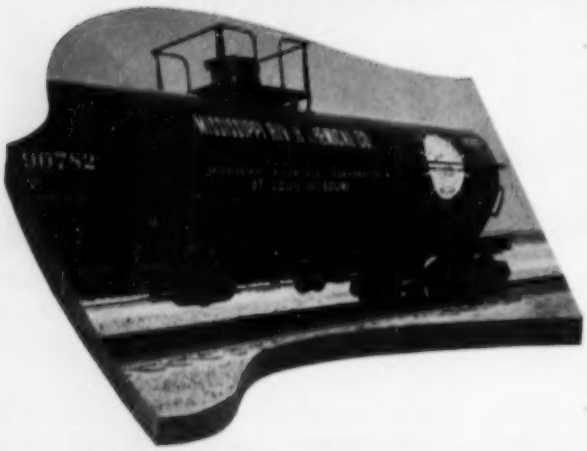
CONSTRUCTION COMPANY

Philadelphia 2, Pennsylvania
Toledo, Ohio
In Canada:
CATALYTIC CONSTRUCTION OF CANADA, LIMITED; SARNIA, ONTARIO

CATALYTIC *ON-TIME* . . . *ON-BUDGET* SERVICES for the metallurgical, chemical, petrochemical and oil refining industries: Project Analysis; Process Development; Process Design; Economic Studies; Engineering; Procurement; Construction; Plant Operation

in chemicals and petrochemicals . . .

FLUOR BUILDS IDEAS INTO PROFITS



"Dependability" is generally considered an intangible . . . yet at Fluor we feel it's the most important single feature we can design into a plant. Take, for example, the chemical-fertilizer facilities we recently completed for Mississippi River Chemical Company at Selma, Missouri. Fluor dependability has seldom been better demonstrated. Responsibility extended from site preparation . . . through adaptation of the basic processes to the specific needs of the customer . . . to completing construction and placing the plant on-stream. Today, the Selma plant works a 24-hour schedule converting natural gas and fuel oil to profit-making anhydrous ammonia, nitric acid, and nearly 300 tons per day of fertilizer-grade ammonium nitrate. Performance like this is what industry means when it says, as it has for 65 years . . . you can be *sure* with Fluor.

Mississippi River Fuel's Selma plant employs the Texaco partial oxidation process to produce hydrogen and the Fluor-Claude synthesis scheme for ammonia (200 tons/day, anhydrous) production. Plant also includes a 220 ton/day HNO_3 unit, a 280 ton/day prilled ammonium nitrate plant, and extensive off-site facilities.

Engineers • Constructors

The FLUOR CORPORATION, Ltd.

FLUOR

2500 So. Atlantic Boulevard, Los Angeles 22, Calif. • Offices in Principal Cities in the United States and Canada

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Advertisers' Products

IFC	3R	4A	6L	7A	8A	10A	11A	12L
13A	14A	15A	16A	17A	18L	19A	21A	22L
23A	24A	25A	26A	27A	28L	29A	30A	31A
32L	33A	34A	35A	36L	37A	38A	39A	40A
41A	42A	43A	44L	45A	46A	47A	48A	50A
128A	53A	55A	56L	57A	58L	59A	61A	62A
63L	63R	64L	65A	66A	71A	73R	77R	80L
808R	81R	82TL	828L	83R	868	87R	88L	888R
89R	90TL	908L	91R	92L	93L	93R	94TL	948L
95L	95R	96L	97TL	97BL	97TR	97BR	99TR	998R
107TL	107BL	107R	108L	109R	IBC	OBC		

Chemical Engineering Progress Data Service

Name .....

Position .....

Company .....

Address .....

City .....Zone.....State.....

☐ I want a subscription to C.E.P. Bill me $6.00 for a year.

April, 1956

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129	130	131	132	133	134	135	136	137	138	139	140	141	142

Advertisers' Products

IFC	3R	4A	6L	7A	8A	10A	11A	12L
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32L	33A	34A	35A	36L	37A	38A	39A	40A
41A	42A	43A	44L	45A	46A	47A	48A	50A
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Chemical Engineering Progress Data Service

Name .....

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Address .....

City .....Zone.....State.....

☐ I want a subscription to C.E.P. Bill me $6.00 for a year.

April, 1956

Pag

the chemical engineers'

DATA SERVICE

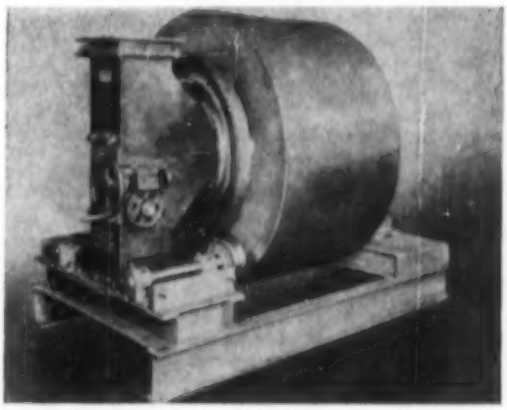
and

GUIDE

to significant developments in

- **EQUIPMENT**
- **MATERIALS**
- **SERVICES**

developments of the month—



188 Heavy Duty Blender. An all-Monel heavy-duty blender for dry blending of bulk solids is announced by The Sturtevant Mill Co. As far as is known, this marks first time Monel metal has been used in this type of blender with a capacity of 1,000 lb. per batch. The blender pictured above has the following advantages other than the obvious ones of corrosion resistance & the ability to handle abrasive materials induced by its material of construction:

1. Both intake and discharge are at the same end of the machine for simplicity of operation. In addition, material can be charged & discharged while the machine is running.

2. A unique 4-way mixing action speeds production while assuring thorough blends.

3. "Open-door" construction permits easy accessibility for simple cleaning & maintenance.

It is expected that the Monel blender will find other uses in the blending of corrosive or critical materials in the chemical process industries.

(Continued on page 68)

TURN THIS PAGE TO RIGHT FOR MORE . . .

HOW TO USE THIS POST CARD FOLDER

Merely encircle numbers on cards to get literature desired. On advertised products in front of magazine, fold this page out to right. For those in back, fold card strip again to right, where card strip is scored for detaching.

products-

advertised in this issue

IFC Distillation. For half century Vulcan Copper & Supply Co. Engineering Division has pioneered in diffusional process operations. If you have such a problem consult them.

3R Drum Packer. Use of the VíBrox Barrel & Drum Packer permits of denser packing, reduces packing time & labor. Sizes for packing from 5 to 1,000 lb. Others for packing bags to 150 lb. B. F. Gump Co.

4A Demisters. Process vessel performance may be improved by use of Yorkmesh units to effect clean separation of liquid from vapor. Otto H. York Co., Inc.

6L Valves. Economical piping, pumps, valves & tanks made from ACE rubber & plastic materials prevent discoloration, waste, odor or metallic pickup in your processes. Investigate. American Hard Rubber Co.

7A Heat Exchangers. Precise operation is engineered into the design of DeLaval Seperator Co. plate heat exchangers. Made of heavy gauge stainless steel they achieve maximum heat transfer.

8 & 9A Process Control. From Foxboro Co. the M/58 Consotrol. Equipped with revolutionary floating disc system, provides unique versatility, precision & stability. Lever-set proportional band adjustment calibrated to 500%.

10A Mixer. Uniform, quick mixing of dry materials in any proportions, wetting dry materials with small quantities of liquid, or dissolving solids in liquid media are functions of the new Nauta mixer from Blaw-Knox Co.

11A Electrodes, Anodes & Mold Stock. A strict system of gaging & inspection are part of the finishing operation on Great Lakes Carbon Corp. materials, providing a plus factor in efficiency.

12L Process Installations. Goslin-Birmingham Mfg. Co., Inc. is prepared to shoulder the entire load from design to finished product. Engineers available for on-the-spot technical consultation & planning.

13A Flowmeter. An easily installed electronic flowmeter, the bearingless Pottermeter, from Potter Aeronautical Co. operates at any angle, at any pressure & at temperatures from —450 to +1200° F. Accuracy ±½ of 1%.

14A Plastic Piping. Polyethylene pipe & plastic fittings cancel need for costly metal units. Reduce installation to one-man job with simple hand tools. Longer life reduces replacement & maintenance. Crane Co.

15A Heat Exchangers. Available from Struthers Wells Corp. a line of Standard heat exchangers in sizes 20 to 400 sq.ft. of surface in variety of materials. Typical units illustrated.

16A Insulation. Called Thermobestos an insulation material for outdoor process industries. Made from calcium hydrosilicate it is molded to size for proper fit. Sizes to 24 in. x 3 in. half sections. Also blocks 6 in. x 36 in. & 12 in. x 36 in. Johns-Manville.

17A Ion Exchange. Use of ion exchange cuts uranium costs. Permutit Co's. process also concentrates metals from industrial wastes. Recommendations applying to your process available.

18L Pump Packing. Chemiseal for all-chemical service & Centrifugal for general packing from U. S. Gasket Co. Belmont Packing & Rubber Co. Catalogs available.

19 & 20A Valves. Rockwell-Nordstrom valves are lubricant sealed for positive shut-off thus affording longer life & instant operation. Designed for rugged service. Rockwell Mfg. Co.

21A Vinyl Foam. A material which brings advantages to many products now in mass production by Girdler Co. Elastomer Process. Basic elements of system shown in flow chart. Votator data book available.

22L Fluid Control. Foster Engineering Co. announce new control valve equipped with ISOFORCE actuator. Said to give greater sensitivity. Sizes start at ½ in. with materials & end connections to suit operating conditions.

23A Atomic Power. Westinghouse Bettis Plant needs qualified chemists, chemical engineers & mechanical engineers interested in atomic development. Write stating your specific interests.

24A Industrial Sieve Shaker. Unit from Central Scientific Co. called Cenco-Meinzer industrial sieve shaker for use in mechanical analysis of industrial materials. Holds six standard 8 in. or 5 in. sieves.

25A Plant Design & Erection. The Lummus Co. offers a design, erection & operation service for new chemical installations of various types. If you plan a new unit consult them.

26A Plastic Pumps. For pumping any one of the corrosive acids employ a Vanton Pump & Equipment Corp. plastic pump. Has no stuffing box, gasket, or shaft seals. Catalog available.

27A Molybdenum Catalysts. "Molybdenum Catalysts for Industrial Applications," a bulletin from Climax Molybdenum Co. gives details of use of this material as a catalytic element.

28L Mixer. From Read Standard Corp. a mixer with a unique shaped bowl presenting a greater ratio of heated surface to mix. Capacities to 750 gal.

29A Molecular Sieves. Linde Air Products Co. offer molecular sieves which dry your gases thoroughly. Remove all traces of moisture. Performance illustrated in graph shown.

30A Controlled Volume Pump. Your metering problem solved with accuracy ±1% using Milton Roy Co. pumps. Exclusive stepvalve liquid end. Pressures to 50,000 lb./sq.in. Bulletins available.

31A Air Separator. Now 40 to 400 mesh output may be increased to 300% using a Sturtevant Mill Co. unit. Sizes 3 to 18 ft. diam. Designed for lifetime rugged service.

32L Steam Jet Ejectors. If you have a vacuum requirement, consult Elliott Co. specialists for recommendations.

33A Controlled-Volume Pump. Called Pulsafeeder it combines best features of piston & diaphragm pumps. Elimination of packing problems achieved by absence of stuffing box. Bulletin covers applications, etc. Lapp Insulator Co., Inc.

34A Pipe Insulation. Called Unibestos material protects intricate & vital systems against heat loss. Available in sectional form through 44 in. O.D. Union Asbestos & Rubber Co.

35A Process Equipment. Conkey crystallization, evaporation & filtration equipment from Chicago Bridge & Iron Co. has operating profit "built-in" by integration of design, engineering & fabrication. Consultation available.

36L Motorpumps. From Ingersoll-Rand Co., Motorpumps. Efficient construction said to enable use of smaller unit. Deliver more gal./min./H.P. used. Catalog gives complete data.

37A Centrifugal Gas Compressor. A 3-stage unit from Ingersoll-Rand Co. said to be largest ever supplied for refinery service. See illustration for details.

DEVELOPMENTS of the month (Cont.)

109 Air-Meter. Hastings Instrument Co. has recently introduced the Model R Air-Meter, a highly accurate instrument for measuring minute air flow movements. It is used in connection with smog, air pollution, & other applications where extremely small air flow measurements are necessary. It has a range of 0 to 30 miles per hour & a logarithmic type meter scale which provides expanded readings in the low velocity range thus assuring excellent readability below 5 mph & unusual accuracy below 1 mph. Responds in less than one second.

(Continued on page 69)

38A Process Equipment. If you plan a new installation, expansion or modernization Badger Mfg. Co. can supply your needs. Facilities & technical skill available for building & testing required equipment.

39A Mineral Filler. Called Micro-Cel material may be used for long list of product improvements at reduced costs. Composed of synthetic calcium silicates produced by combining lime with diatomaceous silica. Johns-Manville.

40A Job Opportunities. If you are interested in jet propulsion read the details of openings in the field available at Caltech Jet Propulsion Laboratory.

41A Filter Aid. Called Dicalite use of this material enables you to filter out particles not seen with a microscope. Chart shows result recent laboratory tests. Other information available. Great Lakes Carbon Corp.

42A Horizontal Process Units. Your problem may be solved using horizontal process units. Designed & fabricated to solve specific needs. For use in many difficult operations. Bethlehem Foundry & Machine Co.

43A Pressure Valves. Eliminate two-stage reducing stations in handling high pressure drops by use of Leslie Co. pressure reducing valves. For steam, air, gas, give 99% accuracy regulation, other advantages.

44L Vapor Conservation Vents. Named Protectoseal units are fully fire protective, simple & easy to maintain. Protectoseal Co.

45A Impervious Graphite Equipment. Called Karbate & used for building process equipment material provides savings in cost & efficiency. Literature available. National Carbon Co.

46A Process Filters. Process Filters, Inc. make available a variety of units for the process industries. Provide efficient, trouble-free, profitable operation.

47A Belt Conveyors. Degradation & dust may be eliminated handling carbon black with Stephens-Adamson Mfg. Co. zipper-sealing conveyors. See details of recent installation in photographic illustration.

48A Catalysts. New alumina & other special base catalysts available from Houdry Process Corp. listed. Manufactured to special standards for uniformity, surface hardness & mechanical strength.

50A Lead Shielding. Whether your need is for lead brick extruded, curved Protecto brick or conventional brick National Lead Co. has it. Other standard forms include sheet, slab or sleeving.

DEVELOPMENTS OF THE MONTH *(Continued)*

110 Product Literature Directory. Titled "This is A-C from A to Z," a 24-page directory of product literature from Allis-Chalmers Mfg. Co. is an alphabetical description of company products & descriptive literature. An addressed, postage-prepaid post card makes it easy to order any desired product literature.

111 Hermetic Vegetable Oil Separators. Bulletin available from De Laval Separator Co. For closed continuous flow refining operation, these units improve quality & yield, are simple in operation.

(Cont. on page 70)

Numbers without letters indicate data available as described in Data Service "Briefs." Numbers with letters refer to further data concerning products advertised in this issue. Letters indicate position of advertisement on page (if more than one on a page)—L, left; R, right; T, top; B, bottom; A indicates full page; IFC, IBC, and OBC are cover advertisements.

Postage Will Be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD
First Class Permit No. 48390, Sec. 34.9, P. L. & R., New York, N. Y.

CHEMICAL ENGINEERING PROGRESS
25 West 45th Street
New York 36,
New York

Postage Will Be Paid by Addressee

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CHEMICAL ENGINEERING PROGRESS
25 West 45th Street
New York 36,
New York

products-(Cont.)

advertised in this issue

53A Saddle Packing. Widespread acceptance of Intalox saddle packing has been the experience of U. S. Stoneware Co. since product was offered. Improved performance said to stem from patented shape of material. Six sizes ¼ to 2 in.

55A Nitric Acid Plants. Recently completed nitric acid plant designed, constructed & put on stream at SOHIO by Chemical & Industrial Corp. is pictured. One of many large capacity installations completed by C & I.

56L Heat Exchangers. In addition to fabrication of heat exchangers Downingtown Iron Works, Inc. specializes in steel & alloy plates. Illustration tells details of story of recent installation.

57A Filter Presses. Automatic, practically continuous filtration now available in a plate & frame type Eimco-Burwell unit from Eimco Corp. Use has improved plant conditions in seven ways all listed.

58L Tantalum. Fansteel Metallurgical Co. offers a booklet on this material. May be used with economy for equipment for a particular process. Consultations available without obligation.

59A Drying & Heating. C. O. Bartlett-Snow Co. are prepared to design & build equipment of exact size & type for your particular product & capacity requirements no matter what type of material you process.

61A Dryers. Drying ranges of Proctor & Schwartz, Inc. equipment makes possible continuous conveyor drying of materials formerly dried by batch processing. Improves quality, increases profit.

62A Plant Design & Construction. J. F. Pritchard & Co. are experienced designers of plants for the chemical industry. Consult with them if you are considering new plant units.

63L Successful Installations. Such results are achieved by J. F. Pritchard & Co. by ability to work with your engineers & designers plus proved ability & technological skill in providing facilities for chemical processes.

63R Silicone Defoamers. These materials increase production, reduce process time & eliminate waste & hazard of boilovers. Two types available from Dow Corning Corp.

64L Filter Presses. As pioneers in the field D. R. Sperry & Co. are qualified to evaluate your specific filtration requirements. Catalog contains charts, tables, diagrams helpful in operation & selection of filtration equipment.

65A Anhydrous Ammonia Plant. The experience, skill & imagination of Catalytic Construction Co. put the plant illustrated into service on time & on budget. Plants for the chemical industry are their special interest.

66A Engineering & Construction. Fluor Corp., Ltd. builds ideas into profits in the chemical & petrochemical fields. They consider dependability the most important single feature in plant design & guarantee it.

71A Heat Exchangers. Employing electronics in the fabrication of shell & tube heat exchangers minimizes possibility of leaks developing no matter how much tubing & how many tube ends are involved. This is only part of Patterson-Kelley Co., Inc. procedure.

73R Engineering Systems. Vitro Corporation of America conceived, developed, installed & operated a comprehensive multiple-range timing system for an Air Force Armament Center. A new laboratory being built makes their facilities available to industry & government.

77R Filters. New built-to-order features available from Industrial Filter & Pump Mfg. Co. A complete filtration engineering service from fluid analysis to installation. Will make recommendations for your requirements.

80L pH Control. Accurate comparators the product of W. A. Taylor & Co. for use in pH, chlorine control. Colorimetric tests may be made on the spot in minutes. Units are durable, lightweight & portable.

80BR Mechanical Seals. Called Dura Seal these engineered rotary seals are made to meet your specific sealing need using selected alloys, carbons & ceramics. May be installed on existing equipment without sleeves or special machining. Duratmetallic Corp.

81R Heat Exchanger. From Niagara Blower Co. the sectional Aero heat exchanger which gives close temperature control with saving of labor, power & water. Faster cooling of industrial fluids.

82TL Walkway & Handrailing. Fabricated from aluminum are a grating walkway & handrailing for use in petroleum installations. Pressure vessels & tanks also available from Washington Aluminum Co., Inc.

82BL Nozzles. Full & hollow cone, flat spray & other types comprise the complete line of the Spray Engineering Co. available from stock. Capacities from ⅛ pint/min. to 4,000 gal./min. Variety of materials.

83R Feed-Water Heating Systems. Illustrated is a recent installation by Condenser Service & Engineering Co., Inc. Whether your need is for a complete system or emergency retubing or repairs call them any hour of every day.

86B Pipe. For specialized use in chemical plants large O.D. pipe from Posey Iron Works, Inc. Fabricated from various materials pipe available 20 in. diam. & larger to meet rigid specifications.

87R Air Pollution System. Called Aerovane this Bendix-Friez system from Bendix Aviation Corp. helps solve air pollution problems. Entire system may be used in dozens of plant applications. Any one unit purchasable for use with transmitter.

88L Standard Industrial Products. The list which includes belt conveyor idlers, bin level controls, portable box car loaders & others are available from Stephens-Adamson Mfg. Co. Bulletin available.

88BR Gear Pumps. These pumps the result of long experience are now solving problems in most industrial fields. Pump many types of materials. Special units for specific applications. Schutte & Koerting Co.

89R Laboratories. Wigton-Abbott Corp. specialize in engineering & construction of research & control laboratories. Your inquiry will be welcomed.

90TL Plastics Reactor. T. Shriver & Co., Inc. announce a new controlled rate plastics reactor which converts resin monomers into polymers in a multiple chamber unit. Available with any required number of chambers.

90BL Filter Paper. Selection of filter paper for commercial filtration is simplified by use of brochure published by Eaton-Dikeman Co. If your product or process is not included a recommendation will be made upon request.

91R Heat Exchange. Called Aerofin these units from Aerofin Corp. said to do the job better, faster, cheaper. One of their engineers is available near you.

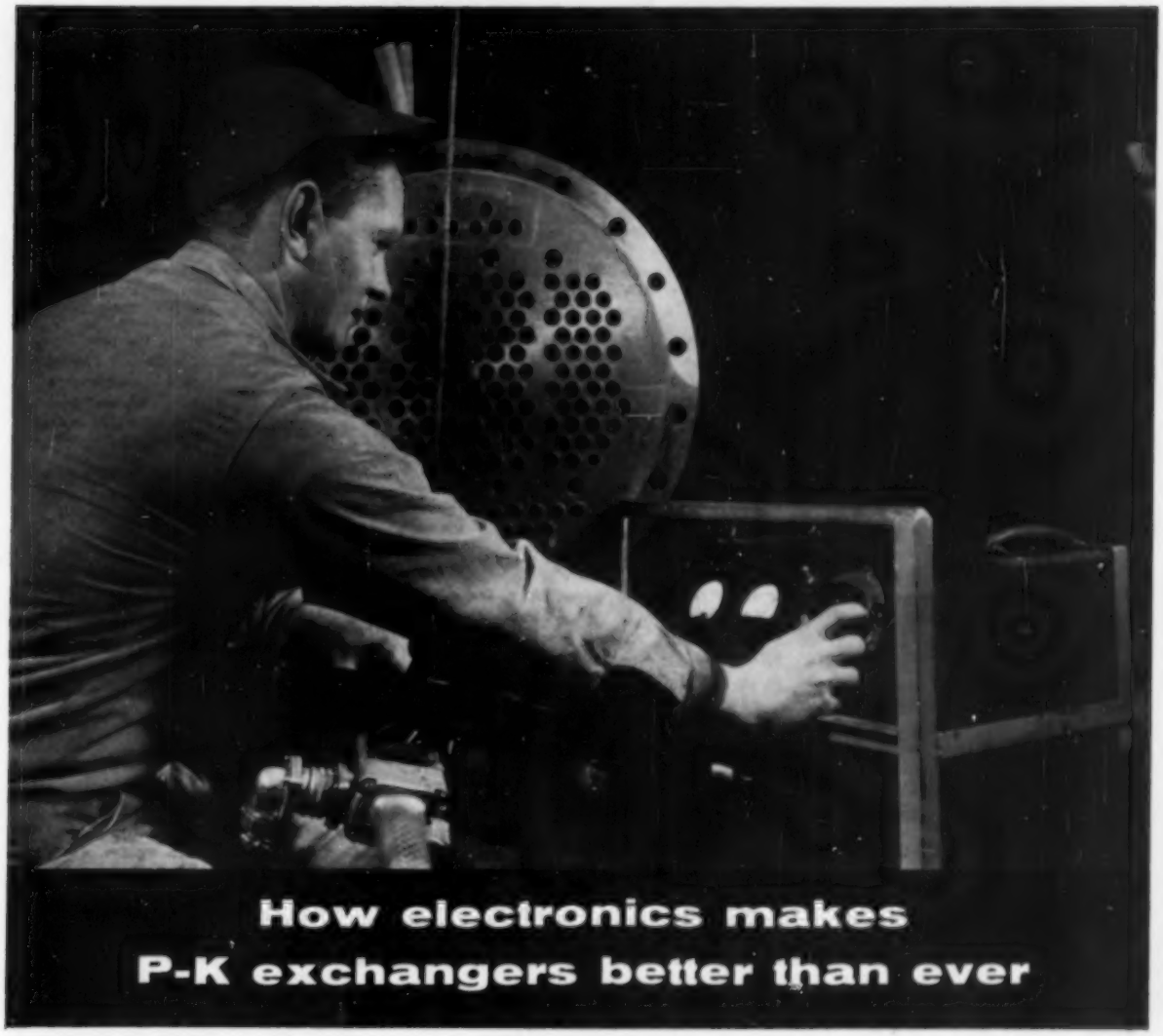
92L Adsorbent. Called Florex this material provides a simple, economical means for protecting expensive catalysts. Customary meshes from 8/16 & up. Floridin Co.

(Continued on page 72)

DEVELOPMENTS of the month (Cont.)

112 Stainless Crolay Tubing & Pipe. Interesting information of value to those associated with the fabrication & installation of process piping is contained in a new folder on welding issued by the Tubular Products Div., Babcock & Wilcox. Folder provides information on the welding characteristics of both austenitic & ferritic types of stainless steels and briefly describes various welding methods & techniques. Includes a table indicating electrodes, preheating & post welding heat treatments to be used in joining stainless steels to each other & to carbon, carbon molybdenum & chromium molybdenum alloy steels by the arc welding method.

(Continued on page 72)



How electronics makes P-K exchangers better than ever

This man is expanding tube ends into the tube sheet—the "inner face" of a shell and tube heat exchanger that holds each tube in place. By doing it electronically, with the equipment you see here, the circumference of each tube is joined to the face of the exchanger with exactly the same pressure.

This minimizes the possibility of leaks developing—even when a mile of tubing and hundreds of tube ends are involved, as they are in many of P-K's special exchangers.

But fabricating procedures like these are only part of the story. Every P-K unit is "computed" for its thermal rating and design.

This automatic check of a unit's thermal rating is not only a safeguard, but can often save you money. And it allows P-K to give a full and complete guarantee that each unit will perform at its rated heating or cooling capacity.

An increasing number of processors, engineers, and contractors have come to rely on P-K's painstaking fabrication and testing procedures —and their check, and double-check, of a unit's thermal rating. We would be pleased to design and build exchangers for you.

The Patterson-Kelley Co., Inc., 1740 Hanson Street, East Stroudsburg, Penna. Offices in principal cities.

PATTERSON KELLEY

2592

Heat Exchangers • Converters • Storage Water Heaters • Condensers • Storage Chillers • Oil Heaters • and all types of heat transfer equipment

products- advertised in this issue *(Continued)*

93L Pumping Report. From Aldrich Pump Co. a Pumping Progress Report describes design, features etc. of pumps in their line. Data sheet available.

93R Motor Windings. U. S. Electrical Motors Inc. winds its motors with asbestos to prevent burnouts from avoidable causes. Coil ends are protected with built up armor of coatings of an asbestic compound. Bulletins illustrate application of asbestos to various U. S. motors.

94TL Liquid Control. Systems for speeding liquids from receipt to delivery are the specialty of Bowser, Inc. Equipment available includes meters & filters, proportioners & blenders, fillers & packagers.

94BL Skin Protection. Damaging substances employed in industry no longer are source of irritation. Use of Kerodex prevents contact with skin. Spreads like a cream & acts like a glove. Ayerst Laboratories.

95L Chemical Engineering Catalog. Published by Reinhold Publishing Corp. volume supplies information on the process industries. Indexed six ways for easy use.

95R Processing & Storage Equipment of Wood. Wendnagel & Co., Inc. feature construction of equipment designed to do tough jobs in chemical processing & storage. Let their engineers recommend suitable construction for you.

96L Gauge. The Ace Glass Inc. McLeod gauge is equipped with Trubore tubing assuring accuracy & interchangeability. New locking device has positive holding action eliminating need for glass hooks & springs. Will hold at any position to which it is rotated.

97TL Spray Nozzles. When next you replace spray nozzles Spraying Systems Co. suggest giving their units consideration. See for yourself how properly engineered, precision machined nozzles can improve performance.

97BL Heat Transfer Units. Standard or special heat transfer units available from Schutte & Koerting include the BD heat exchanger & the Radiafin Air Cooler. Inquiries for special units are welcomed.

97TR Rotary Pumps. Available from stock a low-cost, low-volume pump for corrosive liquids. Capacities 1 to 10 gal./min. Impellers of Teflon, Neoprene or Formica. Suitable for direct motor. Eco Engineering Co.

97BR Grinders. Gruendler Crusher & Pulverizer Co. invites you to send in a sample of your material for free test run & report. Data available for any particular sizing including shredding, pulverizing, breaking, mixing & blending.

99TR Compressed Gases. A new catalog from Matheson Co., Inc. lists all the compressed gases including special ones, gives data on accessories for improving handling, etc.

99BR Gauges. Two types illustrated. Features, other pertinent data listed. Bulletin available which describes other glassware in line. Kontes Glass Co.

107TL Liquid Flow Slide Rule. An instrument which solves flow problems accurately for any liquid in seconds. Calculates pressure drop, flow rate, pipe size. For both turbulent & laminar flow. C. J. Major Co.

107BL Dust Sampling. Joseph B. Ficklen III, designer & manufacturer of continuous gravimetric & oscillating types of thermal precipitators calls attention to the Konisampler for dust sampling with permanent records.

107R Process Equipment. Misco Fabricators, Inc. are prepared to design, & build equipment from heat resisting alloys or stainless steel. All types of standard or special equipment available.

108L Pump Seal. Installing the new Unitary Mechanipak Seal from Garlock Packing Co. eliminates shutdowns for maintenance. Comes ready to install. No on-the-job adjustments required. One of 2,000 styles of sealing materials in line.

109R Jet Equipment. From Croll-Reynolds Co., Inc. a long list of jet equipment available. Information on any of this equipment is yours for the asking.

128A Pumps & Valves. Duriron Co., Inc. specializes in the manufacture of corrosion resisting products including Durcopumps, Durco valves & others. List of applications given.

IBC Sectional Heat Exchangers. Brown Fintube Co. offer sectional heat exchangers which eliminate obsolescence & waste in pilot, semi-works, or full plant operation. Of modular design they may be easily changed from one duty to another.

OBC Mixers. Extra years of fluid mixing are built into every Lightnin mixer. See the list of five ways you get more for your money. Other information available from Mixing Equipment Co., Inc.

Technical Literature • Technical Literature • Technical Literature • Technical Literature

equipment-

1 Instrument Air Regulator. A binder insert data sheet from Black, Sivalls & Bryson, Inc. illustrates & describes the new type 73-26 instrument air regulator which provides close regulation of air supply in pneumatic & other installations requiring extreme sensitivity of pressure output in small volumes of air or other gas. Features are higher air volumes, improved corrosion resistance, & a 40 micron phenolic impregnated cellulose filter. Minimum pressure drift from set point, gives instantaneous response to change of flow rate.

2 Magnets. A newly designed line of non-electric Alnico Perma-Plate magnets which incorporate a new concept of tramp iron removal by the Dynamic principle of magnetic attraction is offered by Dings Magnetic Separator Co. Said to be especially efficient in attracting iron from moving material. Effective range from 2½ in. or under through 4 in. 35 standard sizes, 4 through 72 in. wide available in each basic type. Catalog.

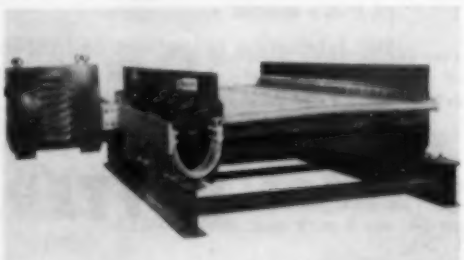
3 Sodium Dispersion Units. Two package sodium dispersion units are now being marketed by Cowles Dissolver Co. One model, the 1000-2000 ml. laboratory unit, the other a 3-7 gal. pilot plant unit. Both jointly designed by Cowles & U. S. Industrial Chemicals Research Dept. Heart of each is the Cowles dissolver an impeller design found extremely efficient in dispersing sodium in an inert organic medium. No loss in dispersing efficiency observed in scaling up from laboratory to pilot plant.

4 Tower Packing. Said to increase throughput up to 3½ times, material called Spraypak developed by the Atomic Research Installation at Harwell, England, manufactured in the U. S. by S. Blickman, Inc. for Fractionating Towers, Inc. In large towers material is assembled in form of interlocking horizontal diamond-shaped cells placed adjacent to & over one another. Illustrated booklet describes material & construction, mechanical design, other details.

DEVELOPMENTS OF THE MONTH *(Cont.)*

114 Heated Screen. New heated screen for use in the chemical process industry, agricultural lime production, clay-handling or other operations where screening is especially difficult because of damp or sticky materials, from Simplicity Engineering Co. Has 35 sq. ft. available screening surface, fully balanced, high speed, short stroke assembly provides positive action.

(Continued on page 74)



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▶ **GET** *up-to-the-minute catalogs, data sheets and bulletins on new chemical products, processes and equipment.*

5 Micronic Filter. A small, cleanable, all metal, (steel or stainless steel) edge-type filter designed by Cuno Engineering Co. for removal of micronic particles from process liquids. Called Super Auto-Klean, unit said to stop all particles over 40 microns, where finer replaceable cartridge type elements are used as secondary filters. Prevents premature plugging of filtering surfaces in secondary cartridges.

6 Submerged Combustion Equipment. An illustrated bulletin on the application of Thermal Research & Engineering Corp. high velocity burners to submerged combustion techniques. Equipment is extremely compact & unique in that combustion takes place external to the liquid being heated. Rated outputs of up to 5,000,000 B.T.U./hr. in a single tube.

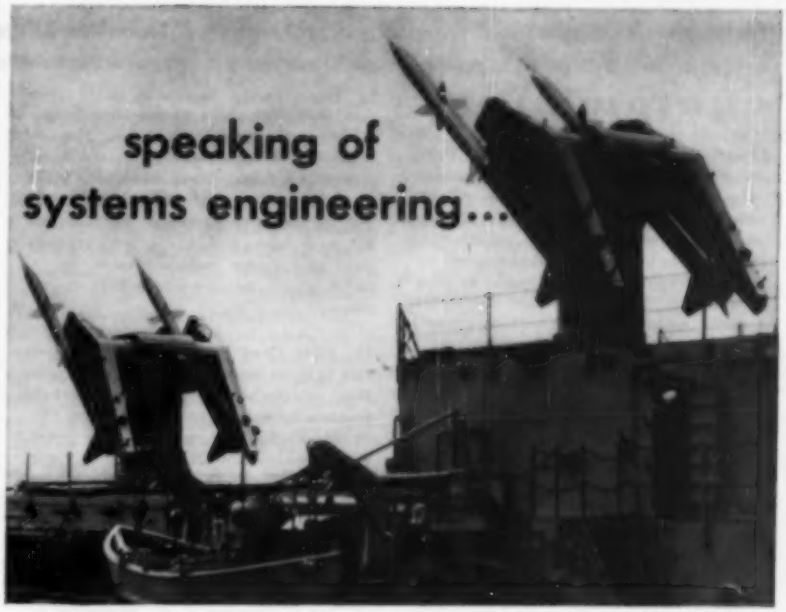
7 Portable Precision Instrument. For use in measurement of oxygen & combustibles in exhaust gases a portable precision instrument from Davis Emergency Equipment Co., Inc. Oxygen is measured by catalytic combustion employing a disposable container of propane. Registers on two-range scale—0-5% & 0-21%. Combustibles measured in separate cell & indicated on individual meter with ranges of 0-3% & 1-15%.

8 Opposed Jet Nozzles. A line of opposed jet impingement type nozzles is offered by Bete Fog Nozzle, Inc. Claimed to have highest possible efficiency of atomization at any operating pressure. No internal parts to clog or wear. Four standard sizes from 3 to 30 gal./min. Pipe connections ⅜ to 1½ in. Fabricated in bronze & aluminum.

9 Recording Potentiometer. A miniature strip chart recording potentiometer weighing less than 25 lb. now available from Westronics, Inc. Equipped with standard charts & ranges for copper & iron constantan, & chromel alumel thermocouples & has internal cold junction compensation. Records on 5 in. strip with pen speed of one second full scale, accuracy better than 0.5%. 3-speed chart drive optional.

10 Industrial Fans. Industrial fans of streamlined design for high efficiency available from American Blower Corp. Provides complete coverage of the full range of industrial requirements & features new packaged industrial fan complete with motor, V-belt drive & running gear enclosure.

(Continued on page 74)



OFFICIAL U. S. NAVY PHOTOGRAPH

THE USS Boston, recently commissioned as the first guided missiles warship in history, carries the newest and most powerful weapons afloat.

Vitro Laboratories takes pride in the Navy's "well done" for its part in the systems engineering of the missiles installation and launching system on the Boston.

Another first in the important new field of systems engineering is the comprehensive multiple-range timing system conceived, developed, installed and operated by Vitro for armament testing at the Air Force Armament Center in Florida. By means of pulse electronics, a time signal generator establishes base "central" time measured in 10,000ths of a second. The system transmits time signals to remote ground and airborne stations for precision command timing and time identification of action photographs.

These are but two of many examples of Vitro's role in systems engineering of the most advanced kind. They are forerunners of significant new systems applicable across a broad industrial spectrum.

Vitro Laboratories is now building a million-dollar laboratory to make its staff and facilities available for new industrial and governmental projects.

Write for detailed information to

VITRO LABORATORIES, 962 Wayne Avenue, Silver Spring, Md.

A Division of

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261 Madison Ave., New York 16, N.Y.

Research, development, weapons systems
Nuclear and process engineering, design
Refinery engineering, design, construction
Uranium mining, milling, processing, refining
Rare metals, heavy minerals, fine chemicals
Ceramic colors, pigments, chemical products

equipment-(Cont.)

11 Miniature Telemeter Receivers. Units are designed for use in graphic panel arrangements & are available as either indicators or strip-chart recorders. Occupy panel space of only 5 sq.in. Indicators & recorders can be used to receive telemetered signals of any of the usual variables such as pressure, flow, temperature, etc. Also electrical measurements like voltage, current, & power. The Bristol Co.

12 Continuous Reactor & Mixing Assemblies. An engineering bulletin from Marco Co., Inc. describes & illustrates with drawings the new Flowmaster pilot-plant continuous reactor & mixing units. Designed to ease the step up from lab-scale continuous processes to full plant production.

14 Gas Heat Exchanger. A high temperature waste gas heat exchanger with unique finned plate design has been developed by Griscom-Russell Co. for recovery of heat from high temperature waste gases. Withstands gases at pressures to 100 lb./sq.in. & temperatures to 1,100° F.

15 Quick Opening Valve. The most recent addition to the line of Klinger Corporation of America products for use in industrial & marine fields is a steel, quick opening valve. For service at 600 lb./sq.in. at 800° F. & 1,200 lb./sq.in. at 100° F., valves are recommended for use on steam, hot water, air, gases, etc. Features are streamline design, & positive openings & closures at pressures of 1,200 W.O.G.

16 Thermal Conducting Cements. New literature from Chemax Mfg. Corp. covers two new products, Tracit-100 & Tracit-200 as well as an older product called Tracit. These cements are used primarily where valves, lines, & equipment are to be heated or cooled by tracing. Said to improve thermal conductivity to 11 times that obtained without Tracit covering.

17 Insulation Material. An insulation product which withstands temperatures of 1,800° F. has been developed by Owens-Illinois Glass Co. Used primarily for covering pipes & vessels this hydrous calcium silicate product has unique advantage of expanding slightly to 1,100° F.

18 Transducer. New applications including ultrasonic processing are seen for an improved barium titanate transducer that markedly increases scope of application of high-frequency utrasonic equipment. Makes possible low-cost ultrsonic processing at boiling temperatures of food, drug, & bacteriological work where transducers must be sterilized; ultrasonic treatment of highly viscous liquids, & others. McKenna Laboratories.

19 Vacuum Gage. A four-station vacuum gage which gives continuous pressure readings from 100 millimeters Hg to 1 micron now available in the U. S. from Consolidated Electrodynamics Corp. Autovac is a self-balancing, direct-reading, hot-wire type gage. High degree of calibration stability.

20 Liquid Level. Applicable to all open type liquid containers & operating in any electrically conductive liquid is Blue M Electric Co's. portable electronic liquid leveler which automatically maintains liquid level of bath mediums to a constancy of ±0.046 in. The packaged unit includes electronic relay, high & low level stainless steel 18-8 probes, solenoid valve, 36 in. nickel plated copper tubing & brass needle valve.

21 Glass Lined Reactors. New construction features now available on small glass lined reactors built by Pfaudler Co. include pressure lubricator for seal on series "P", or construction for high pressure work. High pressure unit rate at 150 lb./sq.in. New hydraulic or air motor drive available. Bulletin on line plus data sheet on type "P".

22 Strainers & Air Eliminators. Rockwell Mfg. Co. announces that it has redesigned its line of strainers & air eliminators for use with liquid meters. Offers new straight-through flow, greater ruggedness & increased versatility. Advantages of new strainers are large screening area & new double-basket construction. Several models. Illustrated binder insert bulletin.

23 Filters. Newly engineered filter housings series QS developed by Cuno Engineering Corp. Designed for process liquids & high capacity lube systems on engines & machinery. Feature easy maintenance, effective micronic filtration, high flow rates, lower cartridge replacement cost.

24 Mechanical-Drive Motor. A new moisture-, dust- & explosion-proof electric motor for mechanical drive applications available from Borg Warner Corp. For use in mining, dry milling, cement processing chemical & other industries. Many models in sizes from 20 to 450 h.p.

25 Fluid Agitators. A packaged fluid agitator service said to be first in the field is offered by Philadelphia Gear Works. One centrally-controlled source solves your fluid agitator problems. Illustrated binder insert bulletin describes construction with cutaway drawings, tables, etc., plus other pertinent data.

26 Temperature Controller. A technical data sheet from Black, Sivalls & Bryson, Inc. introduces Type 1460 temperature controller for positive fluid flow control through diaphragm operated valves, based on temperature variations. External vapor-tension thermal system used to actuate power unit in pilot. Offers choice of temperature ranges.

27 Distillation Apparatus. Precision Scientific Co. announces redesign of automatic distillation apparatus, eliminating tedium of repetitive test chores in quality control. For use in distillation of fuel & other oils, lacquer solvents, crude petroleum, etc. Completely automatic.

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28 Dust & Fume Collectors. Wet type dust-fume collectors are new with the Zack Co. Consist of a cylindrical drum & internal wash-producing structures. Said to have unique, original cone & baffle design resulting in cyclonic washing action, creating turbulence which separates wet dust & carries it to sludge tank for removal. Illustrated bulletin gives other details.

29 Indicating Pressure Controller. Available in ranges from 0 to 50 & 0 to 200 lb./sq.in. a new Minneapolis-Honeywell Regulator Co. unit. On-off or 10% Throttlor control. Case matches that of small-case temperature controller. Data sheet.

30 Positive Displacement Pump. O.K. Machine & Tool, Inc. has a new all-purpose chemical positive displacement pump. Diaphragm type, has pump head, valve components, connecting flanges & nipples of solid Teflon. Liquid being pumped contacts only Teflon. Pumps all acids of high or medium concentration, alkali solutions, petroleum hydrocarbons, & mixtures of these materials at −50 to 300° F.

31 Pressure Gage. A precision instrument said to give continuous & accurate readings of pressure under long exposure to high temperatures & radiation developed by Callery Chemical Co. Application not limited by specific liquids or gases because pressure-sensing bellows may be fabricated from many resistant materials. Bulletin.

32 Surface Thermometer. A compact spot check surface thermometer featuring a range of 50 to 1,000° F., & which operates easily & fast. Made entirely of stainless steel. Thermometer reaches stability in 60 seconds by merely laying instrument on surface to be checked. Also reads ambient temperatures in furnaces, ovens, other enclosed spaces. Pacific Transducer Corp.

33 Heat Exchanger. Type BD an improved design heat exchanger from Schutte & Koerting Co. is made in single- & two-pass designs. Bulletin supplement describes both types, gives data on features, construction, sizes available & dimensions.

34 Two-Stage Canned Motor Pump. From Chempump Corp. a 3 h.p. series unit. Used for handling corrosive, toxic, explosive, other hard-to-handle liquids. Pumping chambers can be piped in series or parallel for high head or volume pumping.

35 Spectrophotometer. A new type double-beam, double-monochromator optical design unit gives fast, high-resolution scans associated with double-beam system, plus spectral purity & extra resolution. Operator can operate unit single beam for high quantitative accuracy. Controls provide flexible operation. Beckman Instruments, Inc.

36 Water Jet Eductors. Bulletin from Schutte and Koerting Co. describes a tank mixing eductor not considered in other literature. Used where desirable to start mixing from shallow level or where uniform local agitation is required over large, shallow tank area.

37 Electronic Control. Developed by Fielden Instrument Div. a low cost solution conductivity controller where recording is not needed. Applicable in water treatment, chemical, nuclear energy, power & metal processing industries. Has two zone action for alarm & control. Ranges of conductivity 0 to 30 micromhos/cm3, or 20 to 200 micromhos/cm3.

39 Manometers. A quick-reference guide to manometer-type instruments now available from Meriam Instrument Co. Four basic types range from simple U-tube to ultra-precision models. Provides selection principles. Specialized units also described for pressure, vacuum, flow & liquid level services.

40 Condensate & Vacuum Pumps. Complete line of vacuum pumps plus Sarco Co., Inc. type S condensate pump covered in late bulletin. Cutaway illustrations, pump selection guide & installation diagrams included.

41 Heat Transfer Apparatus. Sections of various types for use in building cooling & condensing systems for process fluids described & illustrated in catalog from National-U. S. Radiator Corp. Comprehensive reference guide on apparatus in line, data on use in various types of plants, design features, physical characteristics included.

42 Centrifugal Pumps. New with Ampco Metal, Inc. are centrifugal pumps constructed of Illium G alloy. Available for delivery from stock in sizes from fractional flow to 4 x 3 in. Capacities 600 gal./min. at 150 ft. head.

43 Hydraulic Pump. Handling of abrasive & corrosive muds, slurries & solutions is the function of a new hydraulic pressure exchange pump from Manton Gaulin Mfg. Co., Inc. Said to be of revolutionary design eliminating plungers & packing. Positive & permanent separation of product being pumped from contact with moving parts. Pressures to 2,000 lb./sq.in. & capacities to 120 gal./min. Bulletin.

44 Glass Shell & Tube Heat Exchangers. Of special interest to design engineers a manual from Corning Glass Works on Pyrex brand modular glass shell & tube heat exchangers. Aids in selection of correct module for system used. Includes drawings plus engineering data other pertinent information.

45 Infrared Analyzer. Difficult process streams in chemical & petroleum industries may now be automatically analyzed with use of an infrared analyzer manufactured by Applied Physics Corp. Typical application is determination of CO & CO_2 in concentrations of p.p.m. analysis of isobutane in mixtures of pentane & n-butane & determination of HCl-ethylene ratios.

46 Valves. A tight-closing valve with good modulating characteristics & particularly applicable on medium & high pressure pipelines for difficult dead-end or complete shutoff has been developed by Robertshaw-Fulton Controls Co. Binder insert data sheet shows schematic drawing, gives other details.

47 Liquid-Level Controls. Recent automatic controls developed for petroleum producers & refiners by Enniscope may now be applied in chemical industries. Measure fluid levels or interface of two liquids. Handle many diverse liquids including corrosives. Data folio available.

48 Expansion Joints. Flexonics Corp. offers a 24-page expansion joint design guide replete with engineering application & selection data necessary for solution of pipeline expansion problems. Discusses various available types. Also types of pipeline motion solved by such joints.

49 Valve Cover. A line of redesigned Spray-Stop valve covers in only eleven sizes replaces former 142 sizes required. Covers prevent sudden leaks from jetting onto personnel & equipment. Non-indicating, indicating & Teflon covers available. Indicating type warns of leaks by vivid color change. Neirad Industries, Inc.

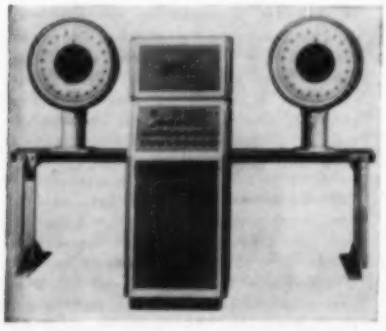
50 Top-Entering Mixer. New bulletin from Cleveland Mixer Co. on series K top-entering mixer. Features include easily changed speed, 2-stage helical gear reduction, flexible agitator, thrust bearing, all steel housing, flange mounting. Data sheets show schematic drawings give all other pertinent data.

51 Centrifugal Pumps. Feature of new general service pumps from Dean Brothers Pumps Inc. is that only three parts—impeller, casing & back head cradle vary with size & capacity of line of seven pumps. All other parts same throughout line. Bulletin shows schematic drawings, gives details of design, construction & specifications.

52 Refractometer. Rugged portable differential refractometer from Phoenix Precision Instrument Co. is designed for direct measurement of difference in refractive index between a dilute solution & its solvent. One ml. of solution & one of solvent required for measurements. Limiting sensitivity about 3 in 6th decimal place & differences in index to 0.01 can be measured.

53 Diaphragm Valve. One of the advantages of the new Wynn diaphragm valve developed by Stockdale Engineering Co. is straight-through flow without dam to trap suspended matter. Two-way leakproof

(Continued on page 76)



Complete Helco-matic system is contained in single console no larger than standard filing cabinet. Combination of material weights & selections the unit can control are unlimited.

Developments of the Month *(Continued)*

115 Electronic Weigh Batching System. A system which will work in conjunction with IBM's punch card system has been perfected by Heltzel Steel Form and Iron Co. Called Helco-matic Batchmaster, it unites for the first time the speed & accuracy of electronics with commercially acceptable weighing units. Using IBM punch cards, the unit automatically selects & weighs out the precise amount of any number of materials.

(Continued on page 76)

To get batch required, operator inserts punch card in slot provided, automatically activating Helco-matic which controls weighing apparatus, gates and valves.

control of acids, oils, slurries & most hard-to-handle fluids. Self-draining valve provides unrestricted path for material to pass across smooth valve floor. Keeps pressure up eliminating necessity for cleaning ports.

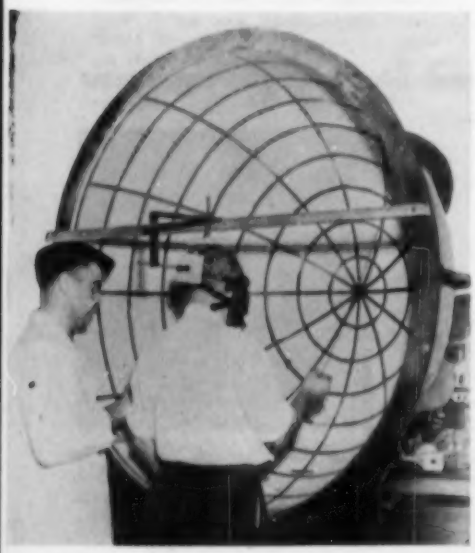
54 Expansion Joints. Called HydroLastic, expansion joints hydraulically formed & dynamically controlled are subject of 24-page catalog from Cook Electric Co. Includes details of construction, specifications, as well as application data for various piping systems.

55 Centrifugal Pumps. Announced by Allen-Sherman-Hoff Co. an improved line of Hydroseal pumps for transporting abrasive materials with high efficiency, from power & petroleum plants. Two types in many sizes. One employs special linings & is suitable for pumping fine solid materials where resistance to chemical reaction is important. The other employs hard metal alloy wearing parts & is suitable for sharp edged solids handling.

56 Mathematical Charts. Two new charts which speed mathematical calculations from Frederick Post Co. Called Calculine they provide an economical tool used for same purpose as calculating machine or slide rule. Consist of a log-scale superimposed diagonally upon a log log grid. Includes scales for multiplication & division. Others for obtaining square or cube root & logarithm of a number.

Developments of the Month *(Continued)*

116 Gas Masks. A special test bulletin which presents maximum usable vision patterns of gas mask equipment is available from Acme Protection Equipment Co. Test data obtained through the use of a Vision Scope (shown in accompanying photo) accurately checks all ranges of vision angles for both single & double-lens types of gas masks.



57 Reflux Heads. Automatic distillation reflux heads for high vacuum, pressure & temperature or for corrosive or hazardous service. Eliminate reflux control problems with simple, accurate operation. Bulletin contains cutaway view plus other information. Distillation Engineering Co.

58 Flow Indicator. A ball-type flow indicator announced by Schutte and Koerting provides a dual scale for approximate measurement of water flow in gal./min. & air flow in cu.ft./min. Inexpensive but sturdily built instrument for indicating water or air flow & approximate rate is exceptionally versatile for industrial use. Bronze indicator stocked in ¼ to 2 in. pipe connection sizes.

59 Process Units. Custom made steel & alloy tanks & vessels for processing industries available from Nooter Corp. New catalog describes facilities & workscope. Includes comprehensive corrosion data tables for various metals.

60 Package Pump. Announced by Layne & Bowler Pump Co. a new pumping unit for wells as small as 4 in. in diameter. Called Vertiline Package Pump it is pre-engineered for ordering by unit number & delivery as complete package. Two sizes, 4 & 6 in. Over 80% efficient on lab tests. Sizes 2 through 7½ h.p.; heads to 340 ft.; capacities 200 to 7,500 gal./hr. Data sheet.

61 Pilot Plant Centrifuge. For use in laboratories, plant research & small scale production unit called Westfalia LG-205 Liquid-SEAL centrifuge. Feature is enclosed, foamless pressure discharge of separated liquids or clarified effluent. Has interchangeable-bowl arrangement. Centrico, Inc. Folder available.

62 Pressure Leaf Filters. New scavenger leaves on Niagara Filters Div., style H horizontal tank pressure leaf filters eliminate unfiltered heel to 1% or less. Heel can be blown down so only 2 to 3 gal. remain in filter tank whose normal heel is 350 gal. Leaves eliminate necessity for holding heel for next cycle. Advantageous for batch filtration.

63 Industrial Fans. A well illustrated 72-page catalog from American Blower Corp. describes the new series 106 Industrial Fans which provide full-range coverage of industrial air & material handling requirements. Lists features, discusses wheels & arrangements, optional construction, modifications & special design & construction for high temperature operation. Section on new Package Industrial Fan, a self-contained unit.

services-

90 High Alloy Assemblies. Folder from General Alloys Co. announces their availability as custom fabricators of high alloy assemblies for the process & allied industries. Describes & illustrates company's specialized services for assembly production. Facilities include modern welding setup, complete foundry, plus chemical & metallurgical laboratories for research & analysis.

91 Dust Control. A series of pamphlets from the Johnson-March Corp. covers their dust control systems, dual-clone cyclones & reverse air jet filters giving a complete picture of their special services in the field of dust control.

92 Fire Protection. Automatic Sprinkler Corp. of America in a recent 28-page well-illustrated booklet cover the subject of fire detection, prevention, control & extinguishment as it is associated with the field of Special Hazard fire protection, & the services they render in this connection.

materials-

95 Castor Oils & Chemical Derivatives. A catalog & product guide from Baker Castor Oil Co. includes information on technical literature, plus chapters on specific castor oils, fatty acids, esters, metallic soaps & specialities, plus various types of charts.

96 Polyethylene Waxes. Possible applications for Epolene a new line of polyethylene waxes developed by Eastman Chemical Products, Inc. are covered in a loose leaf brochure recently released. Gives important physical properties of two types of Epolene, along with tables of compatability with other synthetic & natural waxes, resins & dyes.

97 Silicate Insulation. Titled "Thermobestos Pipe & Block Insulation," a booklet from Johns-Manville. Information given on hydrous calcium silicate insulation for hot outdoor piping & process equipment operating at service temperatures up to 1200° F. Sections on prefabrication of fittings, physical & thermal properties & tables of available sizes & thicknesses. Complete heat transmission tables for both pipe & block insulation.

98 Activated Charcoal. A survey of solvent & air recovery using activated charcoal available in a technical bulletin from Barnebey-Cheney Co. Covers theory & history of solvent air recovery. Using charts, tables & graphs bulletin covers estimated costs & efficiencies of recovery systems for solvents.

99 Uranium Concentration. A flowsheet illustrating uranium concentration known as the "Resin in Pulp" process is available from Denver Equipment Co. System has not been applicable to ores containing vanadium where that material must be recovered. Illustrates individual process steps with diagram & description.

100 Elastomers. The properties, applications, compounding, vulcanization & fabrication of KEL-F elastomer—a fluorocarbon rubber with outstanding resistance to heat & corrosion— form the subject of companion brochures from M. W. Kellogg Co. First of booklets, 16 pages, designed for users or specifiers of the elastomer available in two grades of gum which differ in processing characteristics & vulcanizate properties.

✓ **CHECK** *your Data Service requests on the handy postcard on page 67 to*

▶ **GET** *up-to-the-minute catalogs, data sheets and bulletins on new chemical products, processes and equipment.*

101 Chemical Bulletins. An up-to-date listing with brief descriptions, of all available chemical bulletins, issued by Climax Molybdenum Co. Designated CH-3 the 4-page compilation is available on request. Included are a Chemical Data Series, one on Agriculture, Analysis, Ceramics, Catalysts, Colors & others.

102 Chemical Resistance Chart. Nearly 400 reagents are listed in a new chemical resistance chart available from American Agile Corp. Shows compatibility & non-compatibility of reagents to polyethylene, non-plasticized polyvinyl chloride, high impact polyvinyl chloride & other materials.

103 Chemical Intermediate. A versatile substance useful in preparation of drugs, insecticides, dyestuffs, chelating agents, amino acids & other complex organic compounds, has been made available in pilot plant quantities by Chas. Pfizer & Co., Inc. Called DMADA, the dimethyl ester of acetonedicarboxylic acid it is being actively tested in many industries. Data sheet available.

104 Plasticizer. Properties & characteristics of HB-40 a low-cost secondary plasticizer said to be compatible with many resins, described in bulletin from Monsanto Chemical Co. Widely used as extender-type plasticizer for polyvinyl chloride resins, polystyrene, asphaltic materials & others. Recommended applications listed.

105 Corrosion Proofing. Pennsylvania Salt Mfg. Co. offers a brochure on corrosion proofing materials & techniques. Contains detailed information on cement mortars, interliners & linings for surface treatment.

106 Inhibitors. Developed by O'Brien Industries, Inc. inhibitors for use with sulfamic acid & all sulfate base acids plus phosphoric acid. Effective protection for metal surfaces against attack while in combination with sulfate base acids & phosphoric acid for cleaning operations on evaporators, boilers, other heat exchange equipment.

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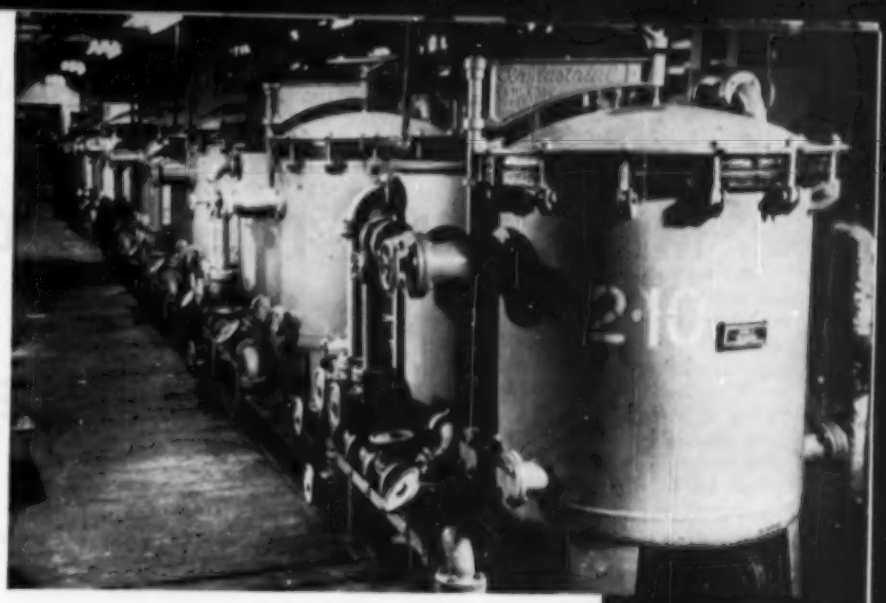

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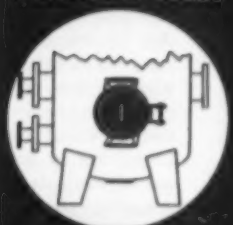

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MEASURING THE PERFORMANCE of ENGINEERS AND SCIENTISTS

R. A. Kinckiner

Deputy Director, Engineering Research Laboratory †

Engineering Department, E. I. du Pont de Nemours & Company

Is it possible to measure the performance of an engineer or a scientist? Many insist that this cannot be done, yet it is being done daily. When a man is selected for promotion or transfer, or is given an increase in salary, his performance has been measured and his potentiality has been assessed, even though it may have been done by intuition. When a scientist asks a co-worker for assistance, he usually has appraised several of his co-workers, although he has almost certainly done so intuitively.

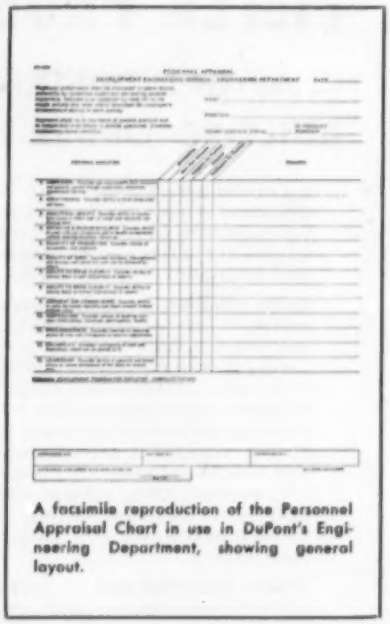
The question then is not whether the performance of engineers and scientists can be measured but how best can the measurement be made. Do we wish to use intuitive judgment alone or more precise methods of analysis and appraisal to assist our intuition? Certainly, as scientists we accept the use of methods and devices to measure scientific phenomena. Why not then use some analytical procedure to appraise the performance of scientific personnel?

Perhaps we can best grapple with the question by reviewing the methods of appraisal that have been developed and by acquiring an understanding of their underlying principles. In reviewing the various methods, a procedure successfully used by the Engineering Department of the Du Pont Company for a number of years will be presented as an illustration of the "Chart System."

THE VARIOUS NON-CHART SYSTEMS

Rank Order System (1)

The persons to be appraised are ranked in order from best to poorest for each personal quality * on which a comparison is desired. When a number of qualities are considered, the ranking must be repeated for the entire group as many times as there are personal qualities, which is time-consuming.



A facsimile reproduction of the Personnel Appraisal Chart in use in DuPont's Engineering Department, showing general layout.

The rankings for each quality of a person can then be added to get a composite ranking. This is one of the most accurate methods for comparing members of a single grouping. All gradings are relative and hence intercomparison between persons in different groupings can lead to false conclusions. If a series of qualities is appraised and it is desired to weight them, a further complication is added. Under these circumstances, the chart system is much to be preferred.

Paired Comparison

Each person in a group that is to be appraised is compared with every other person and rated as superior to the second person or not. Numerals can be used for this purpose giving the superior man a rating of 1 and the inferior a rating of 2. The sum of the ratings will form a list giving the preferred order from the best to the poorest, the lowest number being the best. This system is really a means of arriving at a rank-order rating and is subject to the same limitations and can be used for the same purposes.

Forced-Distribution System (1)

Groups of persons to be appraised are placed into some designated distribution. The one most usually used is 10%-20-40-20-10%, from poorest to best. The group must be placed according to the selected percentages, i.e., only 10% can be in the highest bracket, 10% must be in the lowest and the intermediate groupings must likewise adhere closely to the intermediate percentages; hence the distribution is "forced." Normally, job performance is the only quality graded. Even though only this one quality is considered, extensive statistical examination has shown that because of the "halo" effect (tendency of the appraiser to rate a man at about the same level for all qualities) encountered in more detailed procedures, the "Forced-Distribution System" gives results of equal reliability with greater simplicity.

(*Continued on page 80*)

† **Now Staff Assistant, Development Engineering Division, Engineering Department, E. I. du Pont de Nemours & Company.**

* **The word "quality" will be used in this paper to mean the personal quality, trait, or characteristic that we wish to analyze, compare, or grade. This quality may refer for example to knowledge, analytical ability, quantity of production and the like, or to job performance as a whole.**

PERSONNEL APPRAISAL CHART PLAN USED BY DU PONT ENGINEERING DEPARTMENT

Essential contents of the Du Pont chart are shown in Table A. The chart has been used successfully to appraise the performance of engineers of all types and experience, and of scientists.

The purpose of this appraisal is:

(1) To provide an equitable basis for promotions, transfers, demotions, and releases.

(2) To keep employees informed of their progress and satisfied as to the fairness of their treatment.

(3) To make employees aware of their deficiencies and thus to assist them in improving their performance.

Thirteen personal qualities were selected to analyze the engineer's ability and performance. It is admitted that other qualities could be added or substituted and it is recognized that other words might be preferred to describe these qualities. In fact, the wording has been refined a number of times.

Originally, the various qualities were assigned numerical ratings and a total grading was obtained. These numbers were so misused that they were discontinued. Since only five gradings were possible, accuracy was only plus or minus one grade, or 20%. It was extremely difficult to get this fact accepted by those not intimately connected with the system. The gradings are used to "force" a detailed analysis of each man's performance and capabilities.

As a substitute for the ratings, the appraised person is now placed in one of five groups from best to poorest but the distribution is not forced. Group 1 represents those who have the best performance or the greatest potentiality, those in Group 2 produce relatively less, and so on until Group 5, which contains those that produce the least and have the least potentiality. However, the performance of persons in Group 5 is satisfactory. Where a person's performance is not satisfactory he is transferred or released.

The two lower grades in each quality, designated "marginal" and "inadequate for position," are intended to indicate those conditions where effectiveness is questionable. Normally, the spread is only within the top three grades, with an occasional check in the "marginal" column. Since all of the qualities are considered important to the job, any checks under "marginal" and "inadequate for the position" are the cause for immediate and positive action toward correction. It is perhaps obvious that these two lower columns apply for the most part to employees newly assigned to the job. It is understood by the appraisers that no person will be removed from their supervision for unsatisfactory work unless sufficient indication of poor performance is found in the two lower columns.

At the bottom of the sheet is a block to record a plan for the development of the employee. Normally this block records some action to be initiated by the appraiser or the appraised person. However, a negative answer such as "no action is required" is acceptable if supported by the evidence.

The detailed analysis is also used to develop a written paragraph for each person, which supplements the chart. This paragraph is "forced" to some extent since it must:

(a) Explain gradings if necessary.

(b) Record meritorious performance or otherwise.

(c) Record the engineer's reaction to the rating and interview.

TABLE A

The personnel appraisal chart of DuPont's Engineering Department Development Engineering Division rates the employee's personal qualities as listed below under these categories: outstanding; more than adequate; adequate for position; marginal; and inadequate for position.

1. **KNOWLEDGE:** Consider job requirements both technical and general; gained through experience, education, specialized training.
2. **CREATIVENESS:** Consider ability to think along original lines.
3. **ANALYTICAL ABILITY:** Consider ability to reason from cause to effect and to weigh and reconcile conflicting data.
4. **INITIATIVE & RESOURCEFULNESS:** Consider ability to cope with new situations and to handle assignments without detailed direction, follow-up.
5. **QUANTITY OF PRODUCTION:** Consider volume of acceptable work produced.
6. **QUALITY OF WORK:** Consider accuracy, thoroughness, and facility with which his work can be followed by others.
7. **ABILITY TO SPEAK CLEARLY:** Consider ability to convey ideas in oral instructions or reports.
8. **ABILITY TO WRITE CLEARLY:** Consider ability to convey ideas in written instructions or reports.
9. **JUDGMENT AND COMMON SENSE:** Consider ability to make decisions logically and check himself without definite rules.
10. **COOPERATION:** Consider manner of handling business relationships, teamwork, participation, loyalty.
11. **OPEN-MINDEDNESS:** Consider reaction to opposing points of view and willingness to receive suggestions.
12. **RELIABILITY:** Consider consistency of work and dependence which can be placed on it.
13. **LEADERSHIP:** Consider ability to organize and direct others or secure acceptance of his ideas by associates.

(d) Discuss the situation in regard to the potentiality for and timing of promotion.

(e) List such critical incidents as seem pertinent.

Procedure for Using the du Pont Plan

(1) The "Personnel Appraisal" is made by the rated person's immediate supervisor. The individual "personal qualities" are carefully considered and the appropriate column checked. From this, a "personal development program" for the rated employee is developed and recorded. An alternate procedure is to develop the program during the rating discussion with the appraised person.

(2) Rating is discussed with the next higher supervisor and, subsequently, compared with the past ratings. Any significant differences between the two supervisors or between appraisals must be reconciled or explained.

(3) The analysis is now discussed with the person who has been rated. This step is extremely important. It is my opinion that no plan can be successful unless the results are discussed with the person being rated. To do so allays suspicion, promotes cooperation, secures constructive action more promptly, and is insurance that the appraiser will use more considered judgment.

This discussion may be conducted in one of several ways. Usually a blank appraisal sheet is used and the level of the rated person is developed item by item. The rated person is always told where supervision has placed him and the reason for so doing, using concrete examples wherever possible. An alternate course is to let the man rate himself and then give him the supervisor's rating. Oddly, most persons rate themselves lower than does the supervisor.

Many supervisors work out with the appraised person the "personal development program" at this point. This is a quite satisfactory procedure and, in my opinion, is to be preferred to doing it earlier, because the appraised person has a voice in suggesting ways for improving his own performance, which facilitates its acceptance.

(4) After the interview, the supervisor prepares the paragraph which then accompanies the "Personal Appraisal."

The rated person does not see this paragraph but a statement must be included that everything except the statement on promotability has been discussed with him or if not the exceptions noted for management's decision.

(5) After the supervisor has completed the paragraph, the chart is again sent through line organization for careful checking and approval.

(6) The chart is finally typed, signed, initialed by reviewers and filed.

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MEASURING THE PERFORMANCE OF ENGINEERS AND SCIENTISTS

(*Continued from page 78*)

Because each person is graded in terms of his particular job, persons with quite dissimilar jobs can be included and it will not be inconsistent to have a supervisor rated in the middle bracket and one of his men placed in a higher bracket.

Grading on promotability is usually added by designating a man in one of three classes: ready for promotion, uncertain, and not ready.

Advantages are: simplicity, ease of use, and accuracy when a sufficiently large number are rated. Disadvantages are: unsuitability for smaller groups, for discussion with the rated person, and for rating a number of qualities.

Critical-Incident Method

This method requires the listing on some periodic basis of incidents occurring during the work day that are indicative of some personal quality and good performance, or the lack thereof. To be fair, the incidents must be recorded in sufficient detail and as soon after they happen as is practical. The appraiser thus should spend a brief period at the end of each day recording such incidents.

The complete picture will give an excellent indication of a person's abilities, performance, and limitations. However, it is unwieldy, requiring much time. Further, there is usually little that can be discussed with the appraised person because:

(1) Each incident should be handled at its occurrence if correction is desired.

(2) A fruitless argument about details ensues when the appraised person is shown such a list at a later date.

Comparison is difficult because of nonuniformity, and some other system must be used to obtain a grading, if desired.

Alone it is not satisfactory for measuring the performance of scientists but it is a valuable supplement to other methods.

This method (*6*) was developed during the War.

Freely Written Paragraph

A paragraph is required on each person on some periodic basis, usually monthly or quarterly, giving a summary of the worker's qualities and deficiencies. From period to period,

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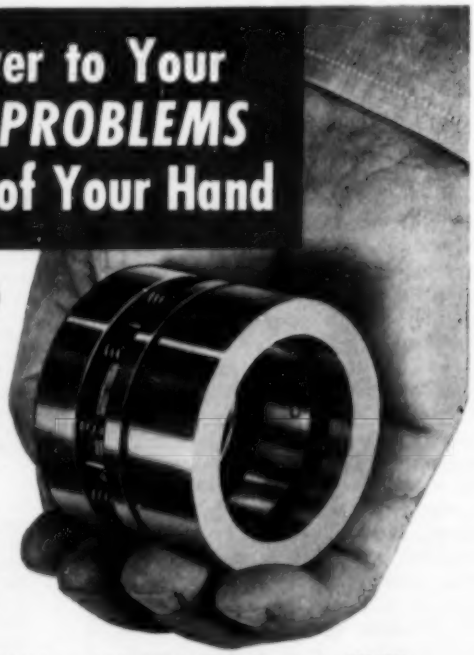

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these should show the worker's progress, performance, and potentiality.

Comparison is difficult because of nonuniformity, the supervisor being permitted to write freely as he wishes. The supervisor usually relies on his memory. This practice will produce less satisfactory results than will the "Forced-Written Paragraph."

Forced-Written Paragraph

This method requires that the paragraphs must cover certain designated areas for each man. It is superior to the "Freely Written Paragraph," particularly if the "Critical Incident Method" is used to obtain substance for the paragraph.

Items usually covered are personal qualities, performance, deficiencies, potential ability, and progress.

The "Forced-Written Paragraph" alone will prove inadequate. Paragraphs are likely to differ widely from appraiser to appraiser. The plan can be used to supplement other plans, however, and somewhat modified is so used in the Du Pont chart plan.

Work-Sampling and Rating

A rater or appraiser (specially trained for the purpose) interviews workers asking them questions to sample their job knowledge. A record of the accuracy of the answers is maintained and the person rated is usually given a numerical grading similar to a college quiz system. The summation of gradings over an extended period is the worker's rating.

As far as is known, this method has been used only for artisans, craftsmen, and manual workers and does not appear to be applicable to technical personnel. An important consideration is the impression that may be made on the rated person during the interview.

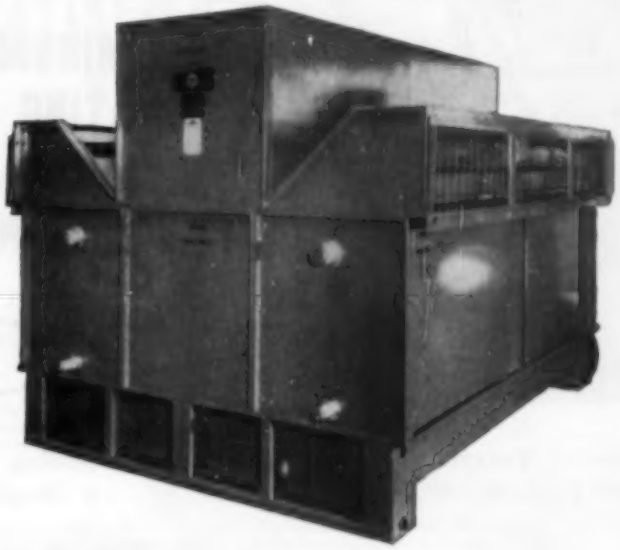
Forced-Choice Method (*2,3,4,5*)

A series of statements or phrases is supplied for the appraiser, who is usually the supervisor, to check. The statements are arranged in blocks of four and each rating sheet will contain from 30 to 50 blocks depending on its purpose.

The appraiser is required to check the statement which is most descriptive of the worker and the one least descriptive regardless of whether or not they apply exactly. The appraiser does not know the value of the blocks or the system of scoring. The system of scoring (*5*) is too intricate to describe herein, but is designed to prevent bias, and studies have indicated that it will do so.

Because this method does not lend itself well to discussion between the appraiser and the appraised, it therefore is

(*Continued on page 82*)



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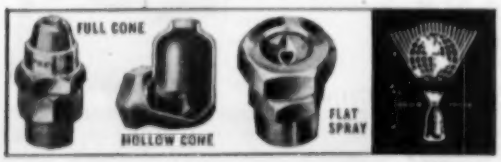

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MEASURING THE PERFORMANCE OF ENGINEERS AND SCIENTISTS

(*Continued from page* 81)

believed to have little value for scientific personnel.

Chart System

By far the larger number of merit-rating plans involve the use of some chart that lists a number of personal qualities with a series of gradings for each quality, thus permitting an analysis and finally some grading of the appraised person. This system appears to be the one most suited for merit ratings of scientific personnel, although some of the systems just described are valuable supplements.

There are scores of these charts in use, each being designed for its specific purpose. Joseph Tiffin (*1*) found that 18 charts used by 18 companies listed a total of 35 traits, qualities, and quantities of performance. The various qualities are usually, but not always, given numerical values which are weighted and can be added to give a numerical grade, indicative of the worker's overall value.

Pitfalls to be Avoided

If the Du Pont chart (p. 79) or any similar chart is to be used successfully, there are several pitfalls that must be avoided.

"HALO" EFFECT

This is the tendency for the rater to decide intuitively as to the worker's level and subconsciously to justify this decision by placing him in approximately the same level in all qualities.

Gradings in individual qualities can vary widely, because an engineer can have superior knowledge in his field, be a penetrating analyst, and yet be quite poor in either oral or written expression or both. With sufficient training and careful attention to the description of the qualities, the "halo" effect can be minimized to a point where it does not significantly affect the appraisal.

INCOMPLETENESS

Raters must understand the importance of using the entire scale and be checked to see that they are doing so. Actually, most raters will not object to classifying each of their workers in accordance with one of four or five groupings in each quality, provided the low end is not given some highly derogatory appellation.

NONUNIFORM RATINGS

If a numerical grading is used, care must be taken in establishing the weightings for each quality and in seeing that the raters understand them. Discrimination must also be used in assessing the significance of the numeri-

cal rating. If one quality is weighted too heavily, the appraiser will be reluctant to assign the appraised person a low rating in this quality because he knows it will count heavily against the appraised person. Qualities in which gradings cannot reasonably be spread over the entire scale should not be included because such qualities tend to mask the differences in final gradings. Health is an example of such a quality. Normally, health either adversely affects a person's work or it does not. Hence it will nearly always be given a top grading and thus mask differences from other qualities.

TRIVIALITIES

There is a strong tendency to list trivial deficiencies in the written paragraph. This tendency is minimized by the necessity of discussing the statements with the appraised person, but the situation must still be watched by those reviewing and approving the paragraphs. Only those deficiencies that significantly affect the work or progress of the employee should be recorded. All of us have some unimportant deficiencies and idiosyncrasies and to record these is wasteful of time and unjust.

If a numerical grading is used, a central agent should check all gradings to see that uniformity of level is attained by all groups. It is not essential that this agent know each man intimately. A plot of numerical gradings by groups will normally show differences in level for groups of reasonable size and such a check should be established.

These pitfalls that confront the appraiser point directly and forcefully to the importance of training the appraiser and of carefully checking the appraisals. This is covered by Tiffin in his paper "Merit Rating: Its Validity and Techniques" (*1*). This paper should be read by all who are using or contemplating some form of "Personnel Appraisal."

Training the Appraiser

The importance of training the appraiser is so great that it is considered desirable to outline the method used by Du Pont in connection with its chart.

The training of the appraiser is done "on the job." No training course is used but a thorough and comprehensive procedure for making the appraisal is given the newly appointed supervisor for study just before he is required to make appraisals for the first time.

After this procedure has been studied, the problems of appraisal are discussed with the newly appointed supervisor by his immediate supervisor. The first group of appraisals are then made jointly by the two supervisors.

Subsequent groups of appraisals are made alone by the newly appointed

(*Continued on page* 95)

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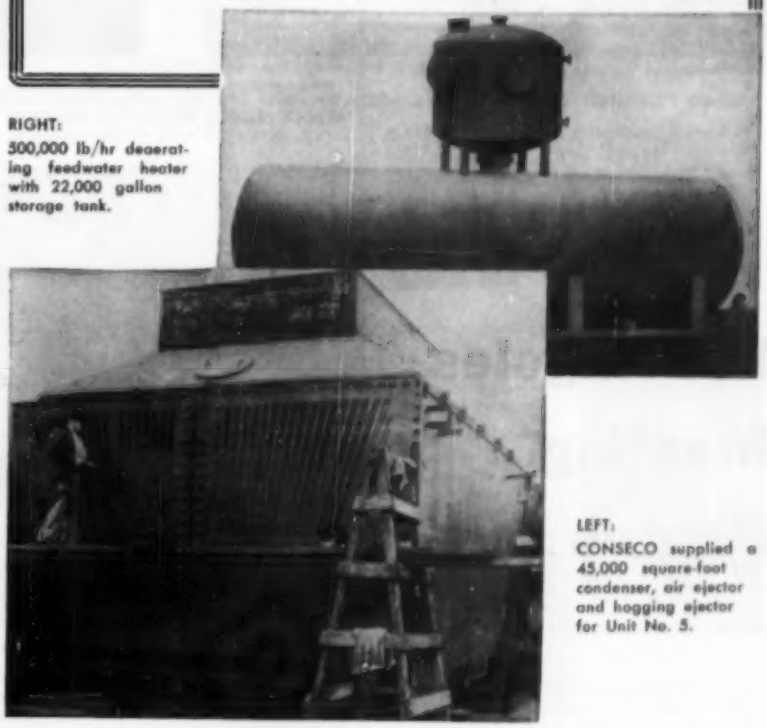

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SEEING COMPUTERS—Chemical engineers visiting the digital (left) and analog (right) computer installations at the Institute of Numerical Analysis Research, U.C.L.A., Los Angeles.

Los Angeles Meeting Photos

ONE OF THE PLANT TRIPS ON THE PROGRAM at the Los Angeles meeting was a tour of the Douglas Aircraft plant at Santa Monica. Here the tour group poses in front of a DC-7B ready for delivery.

PANEL ON SUPERVISION OF PROFESSIONAL PERSONNEL—A good reputation in the treatment of professional employees is a strong asset in recruiting, according to conclusions reached by the panel members shown. L. to r., R. D. Gray, Cal. Tech., moderator; R. W. Krebs, Esso Standard Oil (Louisiana) T. R. Sandberg, Cutter Laboratories; L. T. Lanz, Monsanto; W. S. Martin, Procter & Gamble; and A. L. Lyman, California Research Corp. Panel discussed creativity, leaders, freedom of choice in type of work performed, personnel selection effectiveness, and other factors. A C. E. P. article based on this symposium will be forthcoming.

ROUNDTABLE—Special C.E.P. recording session (basis of article to appear later) on Economic Justification of Process Industry Projects, with the authors of papers from the symposium of the same name. L. to r., Henry E. Wessel, International Minerals & Chemicals, moderator; J. B. Weaver and R. J. Reilly, both of Atlas Powder; H. R. Wager, Arabian-American Oil; F. C. Jelen, Allied Chemical & Dye; Jack Tielrooy, Brea Chemicals; and Norman Krase, DuPont.

PIONEER STUDIES IN AIR POLLUTION—Chairman of the L. A. meeting symposium on Air Pollution Hamnett P. Munger visiting Los Angeles area facilities; left, at So. Calif. Labs of Stanford Research Institute, l. to r., R. D. Englert, mgr. physical sciences research, SRI; L. P. Berriman, chem. engr., SRI; H. P. Munger; W. L. Faith, chief engr., Air Pollution Foundation. Equipment setup in background is used for auto exhaust eye irritation study sponsored by the Air Pollution Foundation. Car on dynamometer is operated under repetitive cycles of varying acceleration-deceleration conditions. Exhaust is mixed with purified air and piped into UV irradiation chamber whence it is distributed to human subjects for reports on eye irritations. Measurements are made of exhaust gas and exhaust gas-air mixture after irradiation. Measured variables include total hydrocarbons, oxides of nitrogen, and oxidants. Top center, same group in front of analytical devices used in test setup. At Cal Tech (bottom center) Mr. Munger with A. J. Haagen-Smit, who is conducting fundamental research into the role of ozone as a smog producing agent. In the experiments shown, a small amount of gasoline is placed in a glass flask containing air, and exposed to the light of ordinary fluorescent tubes. That ozone is formed through the photochemical reaction between nitrous oxide and hydrocarbons is demonstrated by a small piece of rubber, bent to a 180° angle. By looking at the bent portion through the side wall of the flask with a magnifier (1.7ft), it is possible to observe cracks appearing, an index of the rate of ozone formation. Cracks are similar to those which form in the side walls of tires.

C. P. NEIDIG, partner, White, Weld & Co., and a chemical engineer specializing in investment banking, addressing the luncheon gathering on the subject "Is Capital Really Tight in the Process Industries?" Mr. Neidig's answer was "No, thanks to more accurate technologic-risk evaluation methods."

THE MAN SMOG COULDN'T LICK . . .

Ben M. Holt, general co-chairman of the Los Angeles Meeting, shown graciously declining an explanation of how he managed to keep the atmosphere smog-free until 4:59 of the last convention day.

PRESIDENT WHITMAN—Addressing the luncheon, and being interviewed on radio by Dave Showalter in the Hollywood studios of the ABC network, telling the public how the engineers and scientists from the nations of the world got along on a common-sense basis devoid of politics at the Geneva Atoms For Peace Conference, of which Prof. Whitman was Conference Secretary-General.

FUTURE MEETINGS and Symposia of the Institute

MEETINGS **SYMPOSIA**

■ **NEW ORLEANS, LA.**

May 6-9, 1956. Roosevelt Hotel.

Effective Industrial Financial Aid to Colleges

A Sunday afternoon panel discussion to try to resolve means of implementing our growing needs for trained personnel.

Fundamental Mechanism in Boiling, Cavitation and Condensation

To cover the large middle ground between studies of nucleation kinetics and empirical studies of over-all boiling and condensation heat transfer rates.

Foreign Chemical Developments & their Effect on U. S. Chemical Industry

The effect of foreign competition, both commercial and technological, upon the U. S. chemical industry.

Liquid Metals

The fields in which liquid metals have merit and the methods of utilizing them, with particular emphasis on sodium.

Improving Engineering Communications

To advise engineers what is expected of them in engineering reports and other professional communications.

■ **PITTSBURGH, PA.**

Sept. 9-12, 1956. Wm. Penn Hotel.

TECHNICAL PROGRAM CHAIRMAN: Carl C. Monrad, Carnegie Institute of Technology, Pittsburgh, Pa.

Mixing

CHAIRMAN: J. H. Rushton, Dept. of Chem. Eng., Purdue U., Lafayette, Ind.

Distillation Computation Methods

CHAIRMAN: Wayne C. Edmister, California Res. Corp., Richmond, Calif.

Scientific Aids to Management (Chemical Engineering Operations Research)

CHAIRMAN: George D. Creelman, M. A. Hanna Co., 1300 Leader Bldg., Cleveland 14, Ohio.

Case studies showing a wide variety of methods and techniques in applications of operations research in chemical engineering.

Explosions in Chemical Engineering

CHAIRMAN: G. H. Damon, 366 Ashland Ave., Pittsburgh 28, Pa.

Symposium on gas and dust explosions.

Unit Operations in Nuclear Engineering

CHAIRMAN: George Sege, General Electric Co., 2155 So. First St., San Jose, Calif.

How a basic training in chemical engineering fits into the work involved in the field of nuclear engineering, discussing results of unit operations researches done in conjunction with atomic energy projects.

General Papers

Deadline—May 11, 1956

■ **ANNUAL—BOSTON, MASS.**

Dec. 9-12, 1956. Hotel Statler.

TECHNICAL PROGRAM CHAIRMAN: W. C. Rousseau, Badger Mfg. Co., 230 Bent St., Cambridge 41, Mass.

Extraction of Hydrocarbons for Chemical Use from Pipeline Gases

CHAIRMAN: E. E. Frye, J. F. Pritchard & Co., 210 W. 10th, Kansas City 5, Mo.

Filtration

CHAIRMAN: F. M. Tiller, U. of Houston, Cullen Boulevard, Houston 4, Tex.

The flow of liquids through compressible media, with experimental and theoretical papers.

Low Temperature Techniques

CHAIRMAN: Clyde McKinley, Air Products Inc., Allentown, Pa.

The Sales Engineer in Chemical Engineering

CHAIRMEN: W. E. Hesler, Rodney Hunt Machine Co., 420 Lexington Ave., N. Y. C. 17; E. D. Kane, Cuno Eng. Corp., S. Vine St., Meriden, Conn.

Three Panels: "Introducing Mr. Chemical Sales Engineer," "Training the Chemical Sales Engineer," "Performance Yardstick of the Chemical Sales Engineer."

Afternoon at the Ichthyologists

General Session: "Obsolescence" of Chemical Engineers. Sunday P.M.: Round table discussion.

Deadline—August 9, 1956

■ **WHITE SULPHUR SPRINGS, VA.**

March 3-6, 1957.

■ **PHILADELPHIA, PA.**

March 11 through 15, 1957 (probable)

Nuclear Engineering Division Congress and Atomic Exposition, Philadelphia. "The Fuel Cycle."

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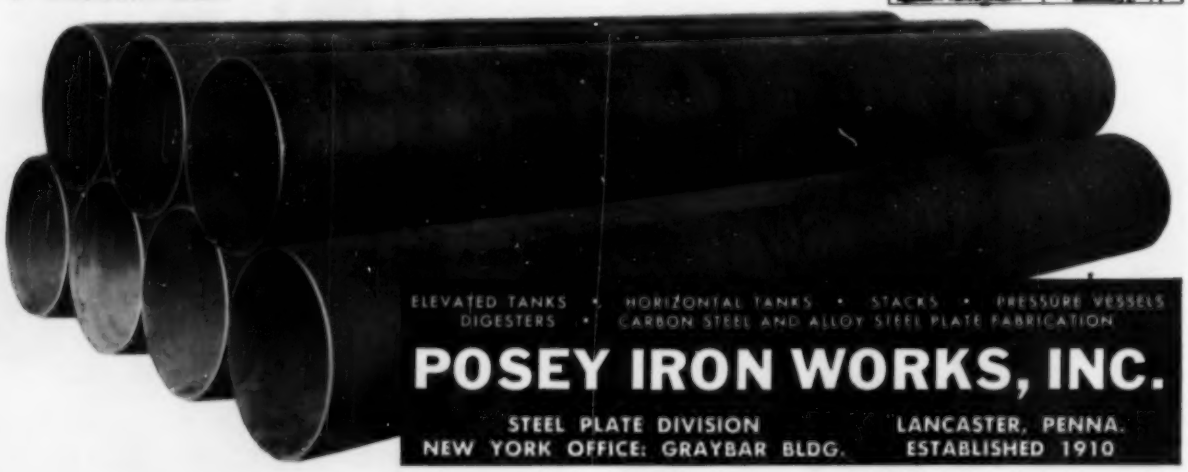

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UNSCHEDULED SYMPOSIA

Correspondence on proposed papers is invited.

Laboratory and Pilot Plant Techniques

CHAIRMAN: Thomas S. Leary, Calco Chemical Div., American Cyanamid Co., Bound Brook, N. J.

Centrifugation

CHAIRMAN: James O. Maloney, Dept. of Chem. Eng., U. of Kansas, Lawrence, Kan.

The theory and quantitative aspects of centrifugation.

Fluidization of Solids

CHAIRMAN: E. R. Gilliland, Chem. Eng. Dept., M.I.T., 77 Massachusetts Ave., Cambridge 39, Mass.

Drying

CHAIRMAN: Ralph E. Peck, Chem. Eng. Dept., Illinois Institute, 33rd Federal, Chicago 16, Ill.

Cost of Unit Operations

CHAIRMAN: John Happel, Chem. Eng. Dept., New York U., University Heights 53, N. Y.

Size Reduction

CHAIRMAN: Edgar L. Piret, Chem. Eng. Dept., U. of Minnesota, Minneapolis 14, Minn.

Filtration & Centrifugation

CHAIRMAN: Horace Hinds, Jr., Corn Products Refining Co., Box 345, Argo, Ill.

Corrosion Resistant Alloy Materials of Construction

CHAIRMAN: G. Fred Our, Carbide and Carbon, Charleston, W. Va.

Dry Classification of Solids

CHAIRMAN: D. W. Oakley, Metal & Thermit Corp., Carteret, N. J.

LOCAL SECTION MEETINGS

■ **NEW JERSEY**

May 1, 1956, Seventh annual all-day meeting. Military Park Hotel, 16 Park Place, Newark, N. J.
D. Q. Kern, Kern Assoc., "Thermal Process Design Without Operating Problems."
R. E. Githens, DuPont, "Recent Developments in Heat Transfer Equipment."
C. A. Ritter, Taylor Instr. Co., "Temperature Measurements Practice and Problems."
J. Y. Oldshue, Mixing Equip. Co., "Heat Transfer in Mixing Vessels."
R. Gunning, Robert Gunning Assoc., "Technical Writing and Dictation."
C. S. Whiting, McCann-Erickson, "Operational Technique of Creative Thinking."
Panel Discussion, "Engineering Manpower Situation."

AUTHOR INFORMATION

Submitting Papers

Procedure to be followed is, in brief:

1—Obtain four copies of "Proposal to present a paper before the A.I.Ch.E.," plus one copy of "Guide to Authors" from Secretary, A.I.Ch.E., 25 West 45th St., New York 36, N. Y.

2—Send one copy of completed form to Technical Program Chairman for meeting selected from above list.

3—Send another copy to Mr. E. R. Smoley, The Lummus Co., 385 Madison Ave., New York 17, N. Y. (Asst. Program Comm. chairman).

4—Send third copy to Editor, Chemical Engineering Progress, 25 West 45th St., New York 36, N. Y. Paper will automatically be considered for possible publication in A.I.Ch.E. Journal.

5—If desired to present paper in a selected symposium, send fourth copy to chairman of the symposium.

6—Prepare five copies of manuscript. Send one copy each to Symposium chairman, Technical Program chairman, or both copies to former if no symposium is involved. Other three copies should be sent to Editor, C.E.P. Presentation at meeting offers no guarantee of acceptance for publication.

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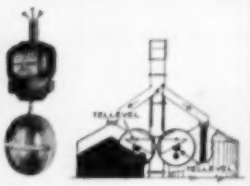

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These names are listed in accordance with Article III, Section 8, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members and Associate Members will receive careful consideration if received before May 15, 1956, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

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Westwater, J. W., *Urbana, Ill.*
Wiedeman, O. F., *New Orleans, La.*
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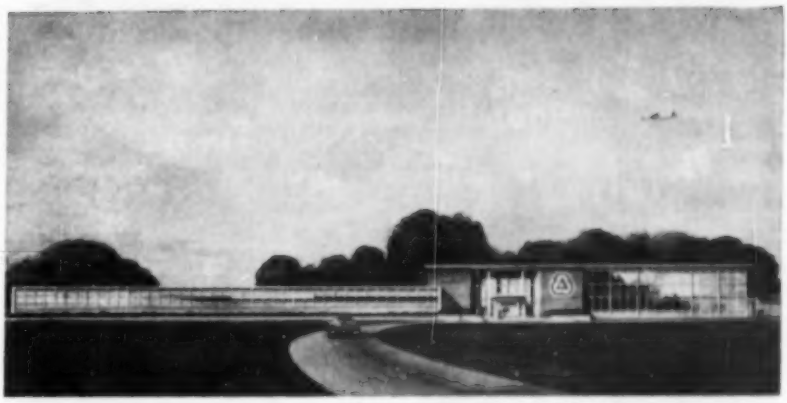

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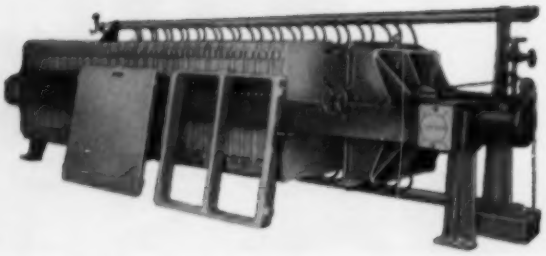

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At a testimonial dinner to **Edward R. Weidlein,** given by the members of the Mellon Institute on March 19th, formal announcement was made of his retirement as president of the Institute. His retirement immediately precedes his departure on a Federal Government mission abroad. Following his return to Pittsburgh, he will continue to serve Mellon Institute as a Member of the Board of Trustees. At the testimonal dinner given for Dr. Weidlein, Matthew B. Ridgway spoke of the great work done by him and the forty years of energetic leadership he has given the scientific research of the Institute.

P. M. Heertjes, professor of chemical technology at the Delft Technische Hoogeschool, Netherlands, is on the staff at Purdue as a visiting professor. He is lecturing in the unit operations and also on dyestuffs and dyeing.

Robert P. Ogden becomes plant manager of the Sharples Chemical division's Riverview works, one of Pennsalt's two major production units located in Michigan.

Otto M. Smith, emeritus professor of chemistry and chemical engineering, and director of the Research Foundation at the Oklahoma Agricultural and Mechanical College, received the Scientific Apparatus Makers Award in Chemical Education at Dallas, Texas. Dr. Smith had a major role in the development of summer workshops to foster high standards of chemistry teaching.

The Whittier, California laboratories of Fluor Corp. announce the following research additions to their staff: **Robert C. Oliver,** senior research engineer; **Donat B. Brice,** research chemical engineer; and **Loren Miller,** research chemical engineer. The men were formerly with Union Oil of Wilmington, Cal.; Food Machinery & Chemical, San Jose, Cal.; and the Jackson laboratory of E. I. duPont, respectively.

Charles A. Heiberger appointed manager of the plastics and polymers department of Food Machinery & Chemical's still-under-construction Central Research Laboratory. Heiberger has been research director for 10 years with the Ohio-Apex Division of FMC.

General Anthony C. McAuliffe will join American Cyanamid May 1. His retirement from the Army was announced in March. At American Cyanamid General McAuliffe is to head the newly-created engineering and construction division, which will have coordinate status with that of the operating and research divisions of the firm; and, in that capacity, he will be president of its engineering subsidiary, Chemical Construction Corp.

W. E. Askey promoted to senior chemical engineer in technical service division of Humble Oil & Refining's Baytown, Texas, refinery.

Raymond M. Albert, of Chemstrand, appointed polymer area supervisor of the Acrilan plant manufacturing department in Decatur, Alabama. He replaces **Robert J. Larson,** who becomes area supervisor, special assignment. In this capacity, Larson represents the Acrilan plant in liaison activities for transferring certain development projects to plant scale. The Acrilan technical department adds **George D. Kellen** and **Willard P. Rhodes** to its staff. Mr. Kellen is a chemical engineer in the quality control section and Mr. Rhodes a chemical engineer in the process assistance section.

B. K. Pospishil is appointed administrative assistant to the vice president and director of research and development for Koppers Co., at Pittsburgh. He was formerly assistant manager of the development section, research department.

Fred C. Hands, formerly manager of B. F. Goodrich's Plant 3 in Akron, Ohio, named manager of the Institute, West Virginia synthetic rubber plant. **Charles Boland Cooper** succeeds Hands as manager of Plant 3 in Akron and **Robert N. Rylands** assumes the duties of production manager, the position vacated by Mr. Cooper.

S. C. Ogburn, Jr., vice president—research and development, Foote Mineral Co., has announced his retirement as an officer of the company, but will continue to serve as a management consultant.

American Potash & Chemical, at Los Angeles, assigns **Hal B. H. Cooper** to its newly-created position of director of development engineering. Formerly, he was assistant director in charge of development for Colgate-Palmolive.

Albert H. Cooper joins American Hard Rubber, N. Y., as assistant to the director of research and development.

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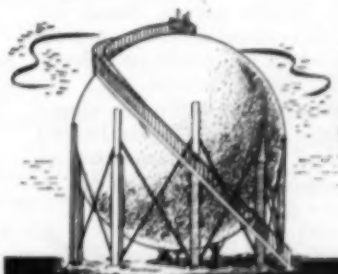

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CHEMICAL ENGINEER TO GUIDE MISSILES PROGRAM

Eger V. Murphree, president of Esso Research and Engineering Co., is appointed to vital position of guided missile development czar by Sec. Wilson.

When Defense Secretary Wilson decided a man was needed as Special Assistant to the Secretary of Defense for Guided Missiles, he looked for a man who was highly versed in engineering and technology, had proven himself as an administrator, knew how to work with people, and "had experience working in a large organization so that he wouldn't get frustrated in this place."

The choice: Eger V. Murphree, until recently (since 1953) a director of A.I.Ch.E., 1950 Perkin Medalist, member of the general advisory committee of the AEC, chairman of the permanent council of the Fifth World Petroleum Congress, president of Esso Research and Engineering—in short, a leading chemical engineer.

Murphree's attributes and experience fit Wilson's four qualifications perfectly. Holder of a B.S. and M.S. from U. of Kentucky, honorary D.Sc. and D. Eng. from Kentucky and Brooklyn Polytech respectively, he has been on the faculty of MIT, served as director of Chemical Engineering Division at Solvay, where he was responsible for the design and initial operation of many new and improved plant operations, and since 1930 has been with Standard Oil (N.J.) working on nearly every phase of the development of chemical processes to utilize petroleum raw materials. He has published widely in the technical journals and holds no less than 32 patents in the field.

Since 1926 he has been in a position of authority in the chemical industry, has proven his administrative ability particularly in the guiding of development programs. Known as "Murph" to his friends, he is a quiet man who rarely raises his voice but gets results.

In his new job, Murphree will have broad powers and responsibilities which will include the "direction and coordination of research, development, engineering and production of guided missiles activities."

Murphree, who lives in Summit, N. J., will serve without pay. He has a big job on his hands.

Noel F. Boyd, former assistant chief process engineer of the chemical plants division of Blaw-Knox, will direct the process department as chief process engineer.

Arthur N. Parrett, vice president of research and development for Rayonier, Inc., moves to the firm's executive offices in N. Y.

Foster Dee Snell, president of Foster D. Snell, Inc., is appointed the representative of the U. S. on the Water, Sewage, and Sanitary Wastes Div. of the Applied Chemistry Sect. of the International Union of Pure and Applied Chemistry.

Charles F. Oldershaw of Dow Chemical is appointed lecturer in chemical engineering at the U. of California for the Spring semester.

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FOR CHEMICAL ENGINEERS

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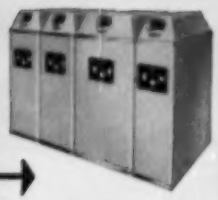

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5554

people

Robert U. Haslanger is elected vice president and general manager of Escambia Bay Chemical Corp. He has recently been assistant to the president and director of sales, industrial chemicals, at Stauffer Chemical. For a number of years he was with Monsanto Chemical where he held various posts in research, product development, and sales.

Emile C. Freeland, N. Y. consulting engineer, will work with a team of Ford Bacon & Davis, Inc., N. Y., in assisting the planning board of the government of Pakistan in the development of an industrial program for that country.

Bradley Dewey, Jr., right, was recently made president of the Cryovac Co. division of W. R. Grace & Co., N. Y. A member of the firm since 1940 after graduation from M.I.T., Mr. Dewey has been vice-president of the division since 1951. W. R. Grace & Co. also announces the election of **T. T. Miller** as president of the newly-created polymer chemicals division.

Carl McFarlin, Sr., elected president of Devoe & Raynolds to succeed **E. William Endter** who is re-entering the petroleum industry. McFarlin is also exec. vice president of Devoe's parent company, Merritt-Chapman & Scott.

Wilbur E. Kelley elected president of Walter Kidde Nuclear Laboratories, Inc., Garden City, L. I. Kelley was formerly manager of the New York Operations Office of AEC.

Frank B. Jewett, Jr., elected a vice president of Vitro Corp. Graduate of Cal Tech and Harvard, Jewett comes to Vitro from 8 years as managing director of engineering research and development with the mechanical division of General Mills.

Nilon H. Prater is now a chemical engineer in the process design section of Chemstrand's General Engineering Department.

Donald L. Rheem elected chairman of the board of Rheem Manufacturing.

Ray M. Ewald is named technical services superintendent for Mobay Chemical's plant in Martinsville, W. Virginia.

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MEASURING THE PERFORMANCE OF ENGINEERS AND SCIENTISTS

(*Continued from page* 83)

supervisor but are very carefully checked in detail by his immediate supervisor, and necessary constructive criticism and action are taken. This detailed checking continues until the newly appointed supervisor has gained the necessary experience and demonstrated his ability to produce reliable appraisals. Since appraisals are made no more frequently than quarterly, such training can extend over a period of several years.

Actually, with the Du Pont method of having several checks by line organization of all appraisals, the training can be considered continuous. The checking, of course, gets less detailed as it progresses through higher levels of supervision, but nevertheless it is of value in the accumulation of experience and in the refinement of judgment of supervision at many levels.

Conclusion

In conclusion, it is my sincere belief that the appraisal of technical personnel can be improved by using some system and I consequently urge those who have the job of administering or supervising the work of scientific personnel to adopt some kind of personnel appraisal plan. If you do not use a plan, you are doing the rating intuitively, and this has been found by experience to lead to unfair treatment.

I also stress that any system must be tailored to the needs of the organization and its specific purpose. Consequently, study the available plans and extract the desirable features of each but *adopt a plan.*

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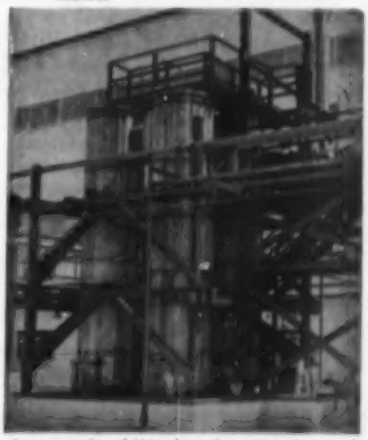

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STUDENTS HEAR OPPORTUNITIES, PROBLEMS AT ANNUAL PITTSBURGH MEETING

The Annual Students' Activities meeting of the Pittsburgh Section awards prizes, hears F. J. Curtis on "Beginnings," has lively panel discussion.

"The chemical engineer at this time seems to be lucky. Actually, he has only exchanged one set of problems for another. (But) this generation will do as well as any of the others—it will be different, that's all."

With these words, F. J. Curtis, vice president of Monsanto, summed up his remarks to the members of the **Pittsburgh Section** (*M. M. Ramer*) and their guest students from U. of Pitt., Carnegie Tech, Grove City College, and the U. of W. Va.

Today is definitely a seller's market for graduating chemical engineering students. One of the big problems of their predecessors, getting a job, does not exist now, but the very wealth of jobs is its own hazard—it puts the young engineer on his mettle in the correct choice for his future.

The situation of a plethora of jobs and a dearth of engineers has come about not only from the expansion of industry, but from a drop in the number of engineering graduates. This means that young men are not going into the field. To overcome this we must pay teachers better, since teachers are the people who have a great deal to do with inspiring a young man toard his future work. We must also show the young man he is not limited to a second level job because he is an engineer, and we must see to it that the engineer who wishes to remain an engineer is not penalized for this by getting less money than his management co-workers or he will simply leave engineering for management as so many have done. In the past, industry benefited greatly from engineers in non-engineering capacities, but today we can ill-afford to lose an engineer from engineering and we must make his reward commensurate with non-engineers.

Nevertheless, the engineer must still be a dedicated man, there is little room for the man out for the "fast buck."

Prior to Curtis' talk, student awards were presented for excellence in chemical engineering unit operations laboratory work to a student in each college. Winners were: H. K. Coble, Carnegie Tech; F. Helsel, Grove; G. Geminder, Pitt.; and J. Dietz, W. Va.

After Curtis' talk he joined a select panel discussing the whole problem of the graduating engineer and industry today. On the panel were: P. W. Bachman, Koppers, and F. C. Frary, formerly Alcoa, representing research; Arne Olsen, Blaw-Knox, and B. J. C. van der Hoeven, Koppers, representing design; E. P. Partridge, Hall Labs., H. Avery, Pittsburgh Coke & Chemical, representing sales; and Fred Denig, Koppers, and P. R. Croll, Pittsburgh Plate Glass, representing production.

CHEMICAL ENGINEERING CONFERENCE HELD IN KANSAS CITY

A day-long meeting, under the auspices of the Kansas City Section, the Mid-Winter Meeting discussed market economics, automation, gas-turbines, and other vital subjects.

The five state area of Nebraska, Missouri, Kansas, Iowa and Oklahoma has had no important increase or decrease in population for a number of years, but farm population has steadily decreased, putting the burden of continued prosperity on the shoulders of industry. This was a major point of C. R. Hathaway, Midwest Research Institute, in his paper on the "Market and Production Potentials for the Kansas City Area." He emphasized that for prosperity to continue in the area, manufacturers must produce specialties which have high value in comparison to their weight so that the area can compete with Eastern Industry.

While automation is certainly here to stay, F. M. Stephens, Midwest Research Institute, indicated that it has not, and will not in future, come without headaches. One major point to be considered is that the designs of many products will need to be changed to adapt them to production by automatic equipment.

(*Continued on page* 98)

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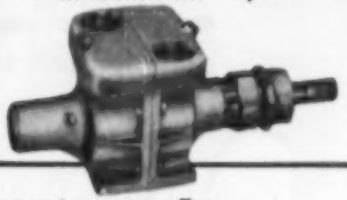

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NUCLEAR ISSUE **JUNE, 1956**

Basic papers on chemical engineering theory applied to the nuclear field will appear in the June issue of the

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A.I.Ch.E. **News of the Field**
FROM LOCAL SECTIONS

(*Continued from page 96*)

Turbines too are probably here to stay, but competition with gasoline and diesel reciprocating engines is going to be keen. Lamont Eltinge, Standard Oil (Indiana) described for the engineers the most likely turbine design which will compete.

"Some Engineering and Economic Aspects of Atomic Power" were discussed by L. H. Landrum and S. A. Zagnoli of Spencer Chemical, and in the more technical vein, F. Kurata, U. of Kansas, presented a paper on "Low Temperature—High Pressure Techniques"; S. M. Wallace, U. of Kansas, presented his on "Representation of Binary Vapor-Liquid Equilibria by Zygographs"; and N. G. Miller, Phillips Petroleum, discussed "Entrainment Variables in a Commercial Vacuum Distillation Tower."

ATOMS, INTERNATIONAL SITUATION, PROFESSIONAL MANPOWER, HEAD LOCAL SECTION MEETINGS

Still high on the list of favorite subjects for local section meetings are atomic energy, automation, professional development, international news, and technology.

The shift to atomic power generation will not be soon. This was the crux of R. T. Overman's Oak Ridge Institute of Nuclear Studies talk to the February combined meeting of the **South Texas Section** (*G. B. Gibbs*) and Southeastern Texas ACS section. With the largest reactors, power costs would be 13-17 mills per kilowatt. Atomic power will make its first inroads into countries without conventional power generation materials and facilities, where it could be considered cheap power. At the same time, the possible industrial applications of atomic energy are unlimited. Research reactors are not expensive in comparison with other research tools—a workable one should cost about $400,000.

For those countries where fuel is now high-cost or non-existent, the small power reactor is probably the answer, according to Mark Lyons, General Electric, speaking at the December meeting of the **Louisville Section** (*F. G. Smith, Jr.*). Other major uses for the small reactors, with capacities up to 30 megawatts, are: military bases in out-of-the-way places;

remote industrial sites near raw materials but no power; and sparsely settled rural districts lacking power distribution facilities. The small power reactor will be a packaged deal, ready to use with a minimum of installation. The dual-cycle boiling reactor is now favored due to its greater thermal efficiency, its exceptionally high degree of inherent safety, a self stabilizing power level to match load variations from 25% to full output, and sufficient control to override reactor "poisons." Slightly enriched uranium oxide rods will serve as fuel, control is by hydraulically actuated pistons moving vertical rods.

The importance of the question of power reactors cannot be overestimated since, according to H. S. Isbin, U. of Minn., speaking to the February meeting of the **Twin Cities Section** (*E. J. Murray*), the relative success of the

Twin Cities (L. to r.): G. W. Preckshot, chmn., H. S. Isbin, speaker, A. L. Frye, vice chmn.

nuclear power projects now under way will determine the rate of growth of nuclear energy. Isbin also emphasized that the chemical engineer has the key role in nuclear energy development if he wishes to apply himself to it. In another area of the atomic field, Isbin pointed out that the use of radioactive isotopes has already saved industry several millions of dollars, will probably save several billions annually in the near future.

Technical Writing

Eighty per cent of our impressions come through our eyes, thus it is at least four times as valuable for the engineer to have his material published rather than just listened to. With this strong statement, R. L. Dudley, publisher of *Petroleum Refiner*, went on to list the specific reasons why an engineer should publish to the January meeting of the **South Texas Section** (*G. B. Gibbs*). Five reasons are: it makes him more widely known; it adds to prestige; it adds to the technical prestige of his company; it adds to the general knowledge from which he has often drawn and should contribute to; and it stimu-

(*Continued on page* 100)

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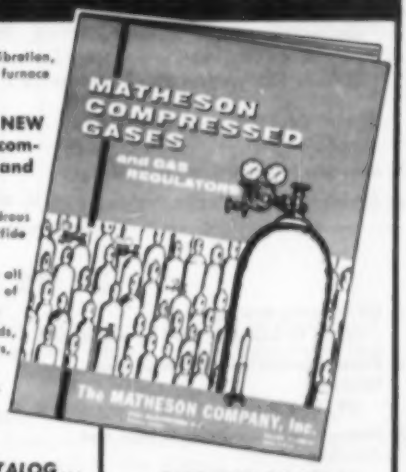

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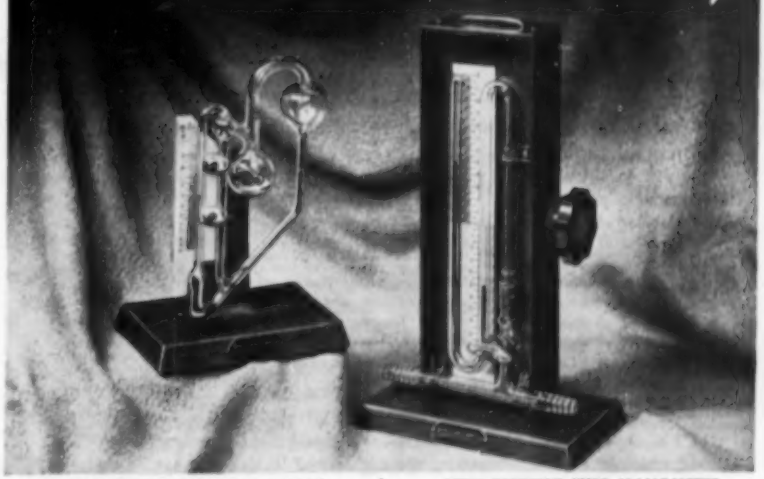

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News of the Field
FROM LOCAL SECTIONS

(Continued from page 99)

lates others to contribute. For the engineer's company the gains are also many: recognition for a valuable employee and for the company; adds to the general fund of knowledge from which the company profits in its operations; raises the self respect of the employee which always makes him more valuable to the company.

At the November 30 meeting of the **Washington-Oregon Section** (*G. C. Szego*) a three-man team tackled the same problem of technical writing from the aspect of report writing: A. T. Walton, Simpson Logging Co., J. H. Holloway, Rayonier, and J. W. Souther, U. of Wash. Consensus: a report is an action document and the principal problem is to get the words off the paper and into people's heads. For this, reports must be designed, not just written, with particular attention being paid to the nature of the audience. It is the responsibility of the university to turn out engineers who can write, but industry must teach them how to communicate effectively in their field.

Manpower and Professionalism

The chemical engineer can increase his value to society and to his employer through active participation in his professional society. This was the theme of F. J. Van Antwerpen, executive secretary of A.I.Ch.E., in his talk to the February meeting of the **Maryland Section** (*D. E. Evans*). Not overlooking the many advantages for the professional development of the individual engineer to be found in his professional society, Van Antwerpen stressed the technological advances made through standards and codes established by the professional engineering societies. For A.I.Ch.E. itself, one of its most active fields is the promotion of good employer-employee relationships, exemplified by the recent (Nov. 1955) publication in *C.E.P.* of the statement on Professional Standards. He also indicated that A.I.Ch.E. is now the fastest growing engineering society.

Turning to manpower, Maynard Boring of General Electric contrasted European methods of producing trained engineers with those of the U. S. for the January meeting of the **Western Massachusetts Section** (*C. H. Fawkner*). College entrance requirements in Europe are generally higher than here, resulting in a small 12% attrition rate compared to 50% in this country. Not

(Continued on page 107)

CLASSIFIED SECTION

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3. Chemist with some research background for work with research division in liaison with patent attorneys. Some experience in this area essential, and preferably in the petroleum industry.

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This position will require extensive experience with very complex fluid flow problems, such as are encountered in the following types of equipment: distillation, dust collecting, filtration, grinding, drying, materials handling, absorption-extraction, and agitation and mixing. Successful applicant will develop specialized equipment such as jet reactors, jet compressors, jet absorbers, and pipe line reactors, and provide technical advice on fluid flow problems involved in handling slurries, plastics, highly viscous polymers, dispersion, and semi-solids.

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Applicants selected will make independent analysis, exercise individual judgment and coordinate the work of others while engineering and designing process equipment including tanks, vessels, distillation columns and machines. Equipment arrangements and piping work will also be included. Assignments are challenging and creative with full recognition for achievement.

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Box #7-4

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CHEMICAL ENGINEER—Ph.D. Twenty years' industrial experience in petroleum, petrochemicals, organics. Desires responsible position in development, design or technical service. Box 12-4.

CHEMICAL ENGINEER—A.B., B.S. Age 34. Thirteen years' research and development experience on synthetic polymers, especially films, fibers, foams. Administrative abilities. Desire Northern New Jersey—Metropolitan New York area. $10,000 min. Box 13-4.

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CHEMICAL ENGINEER—B.S.Ch.E. Age 30. Seven years' diversified production experience. Desires permanent position with chemical engineering work in process development or design. Box 17-4.

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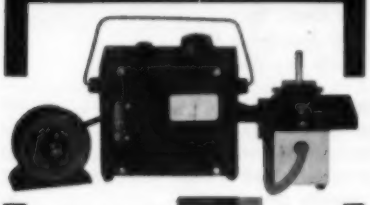

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News of the Field
FROM LOCAL SECTIONS

(*Continued from page* 100)

only is our attrition rate high, indicating lack of previous careful selection or preparation, but the actual number of students entering engineering has dropped, although the trend is now reversing. A major cause of this is the lack of incentive imparted to high school students to enter engineering, and the fact that, due to the shortage of proper science teachers, our high school students are getting much less science training. We do make better use of our trained engineers after graduation than most European nations, but there seems to be little doubt that Russia is ahead of us both in training and proper utilization.

Engineers Abroad

The subject of European chemical engineering was the subject of two other meetings, the January meeting of the **Oklahoma Section** (*L. A. Warzel*) and the February meeting of the **Charleston Section** (*A. W. Byer*). W. B. Reynolds, Phillips Petroleum, told the Oklahoma engineers that concentration of consumer market, availability of raw materials, and the lower cost of labor are three important items of difference between European and American chemical industry. Engineers in Europe receive a lower rate of compensation than American engineers but are held in high esteem in their communities.

While European industrial chemical technology probably lags behind that of the U. S., it is rapidly improving and may very well surpass us if we become complacent, according to S. D. Kirkpatrick, editorial director of McGraw-Hill's chemical magazines, speaking to the Charleston Section. Chemical engineering is just beginning to come into its own as a profession in Europe, despite considerable resistance from the older scientists who still favor the chemist, and the chemical industry is booming, partly through American technological advances.

Automation

In the last five years electronic computers have increased in speed 10,000 times with only a four or five-fold increase in cost, Charles Benton, Jr., IBM, told the March meeting of the **East Tennessee Section** (*R. F. Hunt, Jr.*). While industry still uses the machines mainly for accounting work, active growth is expected from here on in their use for engineering and process control.

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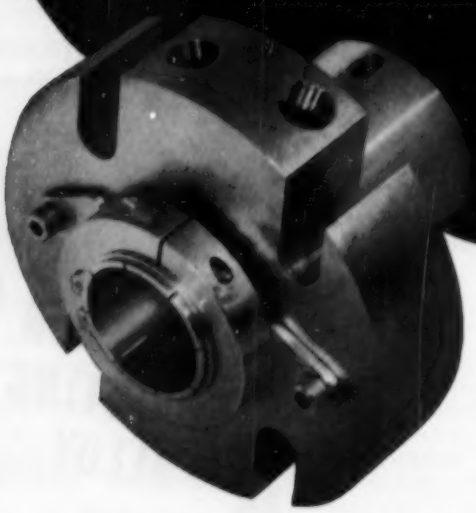

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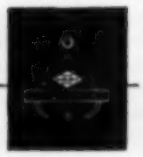

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news and notes of A.I.Ch.E.

HOW Council Works: In recent months I have had a great deal of pleasure in speaking to many Local Sections, where one of the questions most frequently asked me is, "What are the functions of Council?" . . . Rules for Council are laid down in Article V of the Constitution . . . Council spends the most time on the proviso of Section 1 of the article, 'that Council shall have supervision & care of all property of the Institute & shall transact all business of the Institute for it & on its behalf' . . . There are a minimum of six Council meetings a year . . . The preliminary agenda are discussed with the Executive Committee by the Secretary & copies with all supplementary documents are sent to all members of Council at least ten days before the meeting . . . Committee Chairmen are invited & members of subcommittees, etc., are asked to report . . . Routine matters are handled by the Executive Committee via mail ballot with minutes approved by all Council members . . . The load on any member of Council can sometimes be heavy, particularly when a special problem is under discussion . . . At present each Council member is responsible for liaison with a committee & also with a number of Local Sections . . . On top of that, special tasks may be assigned . . . As an example, Vice-president J. Henry Rushton is this year heading the Sections Activities Committee & is charged with investigating & improving the whole system of communication with Local Section officers . . . Council Member D. F. Othmer is examining the reasons that impel students to join or not to join the Institute . . . The work of Council may be illustrated by the Council Meeting at Los Angeles . . . Most of the morning was devoted to a report by Blaine B. Kuist, Institute Representative to the Engineers Joint Council—Engineers' Council for Professional Development Joint Committee on the Practice of Engineering . . . The A.I.Ch.E. has never formulated completely an attitude or policy on registration of Engineers; instead, it has met each problem as it arose . . . Consequently, with many sticky problems coming up in this area, Kuist discussed with Council his actions & attitude toward registration . . . Recent laws provide for registration of officers, directors & stockholders of engineering corporations, & Council finally evolved the tentative policy that A.I.Ch.E. should recognize the need for a program which enhances the public's regard for individual engineers, but that only the engineer in responsible charge of the engineering work need be licensed . . . Council also at Los Angeles, as reported last month, amended the by-law to increase registration fees at meetings, voted to change the dates of the White Sulphur Springs Meeting & of the Nuclear Engineering Division Meeting & Atomic Exposition . . . It voted changes in the by-law covering Student Member subscription to A.I.Ch.E. publications . . . heard, considered & thoroughly discussed a report of the Subcommittee on Professional Standards . . . agreed to the recommendation that the name of the Industrial Waste Disposal Committee be changed to Pollution Control Engineering Committee . . . discussed the financial statement and budgets of the Institute . . . approved new Local Sections . . . acted on the recommendation of the appropriate committee to accredit certain curriculums . . . voted the appointment of R. P. Genereaux as Institute representative and J. C. Lawrence as alternate to the A.S.A. Planning Committee on Standardization in the Field of Nuclear Energy . . . appointed the **Nominating Committee** composed of B. F. Dodge, chairman and member of Council, New Haven, Conn.; A. W. Fisher, Jr., Lexington, Mass.; R. P. Genereaux, Wilmington, Del.; D. L. Katz, member of Council, Ann Arbor, Mich.; B. B. Kuist, Whittier, Calif.; J. W. Mason, Decatur, Ga.; W. L. McCabe, New York; E. N. Mortenson, Hammond, Ind.; Mott Souders, Emeryville Calif.; and C. A. Stokes, member of Council, Houston, Tex. . . . **Intermountain Chemical Engineers** will supply the University of Utah & Brigham Young University with plaques shaped like the Institute shield, upon which the names of outstanding graduates in chemical engineering are to be inscribed. . . . **Student Chapter Counselors** newly appointed: Columbia University, Sheldon Friedlander; N. Y. U., William H. Kapfer; Stanford, David M. Mason. . . . **Presidential trips** are currently being arranged . . . One was made immediately after the Los Angeles Meeting, one will be made during April, & a third will precede the New Orleans Meeting . . . President Whitman's trips have been planned to cover the following local sections: Philadelphia-Wilmington, Central Pennsylvania, St. Louis, Kansas City, Tulsa, Dallas, South Texas.

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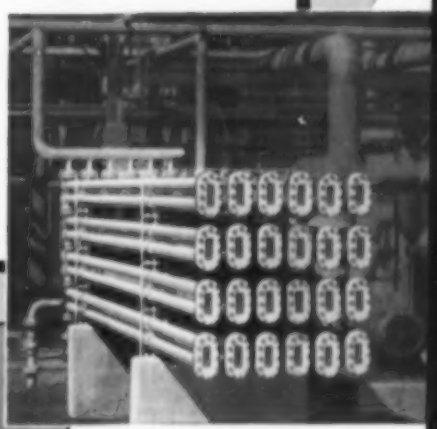

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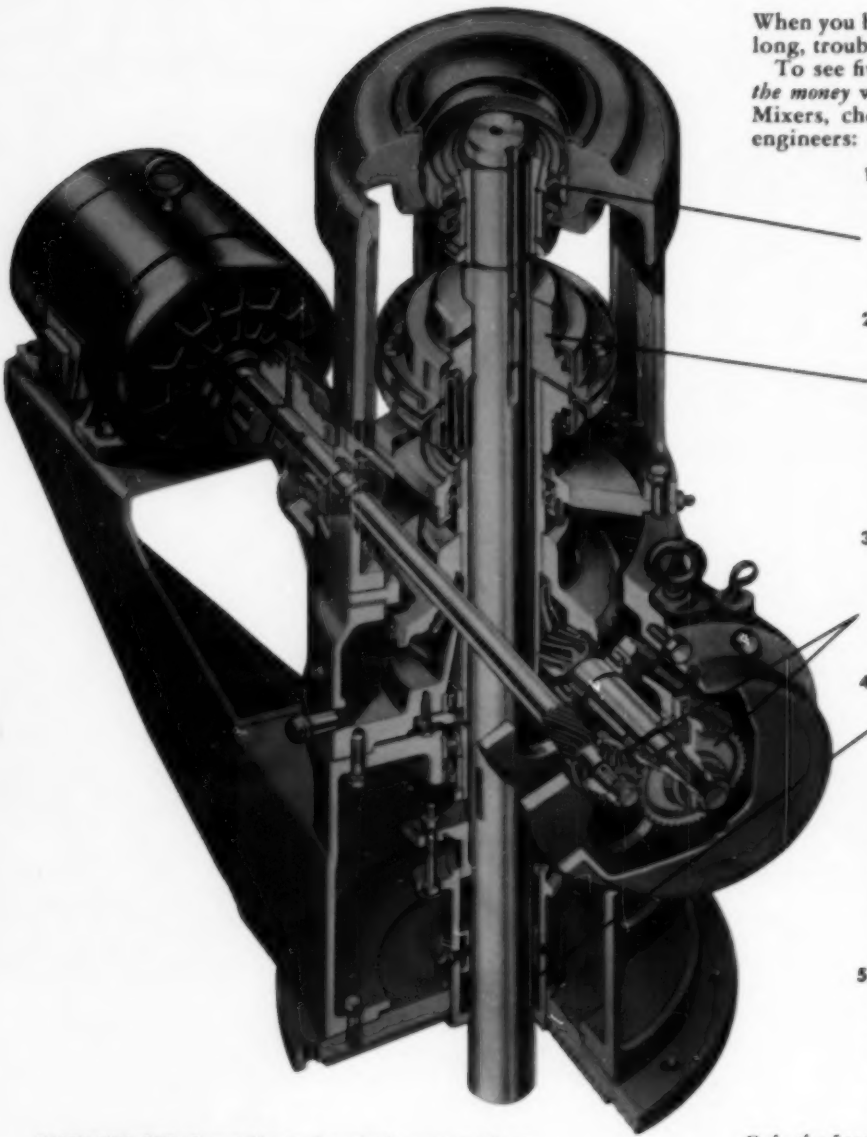

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